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The Impact of Gestational Diabetes Mellitus and Maternal Oral Microbiome: A Scoping Review

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THE IMPACT OF GESTATIONAL DIABETES MELLITUS AND MATERNAL ORAL MICROBIOME: A SCOPING REVIEW

by

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ABSTRACT

Background: Gestational diabetes mellitus (GDM) is a common pregnancy-related metabolic disorder associated with adverse maternal and fetal outcomes. Recent research has highlighted the potential role of the oral microbiome in the pathophysiology of various systemic conditions, including diabetes mellitus. However, the impact of GDM on the maternal oral microbiome remains relatively understudied. Understanding alterations in the oral microbiome during pregnancy complicated by GDM could provide valuable insights into the mechanistic links between systemic metabolic disorders and oral health.

Objective: The objective of this scoping review was to comprehensively examine the existing literature on the relationship between GDM and maternal oral microbiome composition and diversity. The review sought to identify the microbial changes associated with GDM and explore their potential implications for maternal oral health and pregnancy outcomes.

Design: Following PRISMA-ScR guidelines, a systematic search of electronic databases, including “Pubmed” and “Web of Science,” was conducted to identify relevant studies investigating the impact of GDM on the maternal oral microbiome. Eligible studies included those examining microbial diversity, abundance, and composition in pregnant women with GDM and their neonates. Data synthesis involved summarizing key findings and identifying patterns across studies.

Results: A total of eight primary studies were identified and included in the scoping review. These studies employed various methodologies, including observational reports, longitudinal analyses, and cohort studies, to investigate the relationship between GDM and the maternal oral microbiome. Findings from these studies revealed distinct alterations in oral microbial profiles

among neonates and pregnant women with GDM compared to healthy controls. These alterations encompassed shifts in microbial diversity, abundance, and composition, suggesting potential biomarkers or indicators of GDM status within the oral microbiome. Longitudinal analyses further elucidated dynamic changes in the oral microbiota throughout pregnancy and postpartum, underscoring the temporal nature of these associations.

Conclusions: The synthesis of evidence from the scoping review highlights significant associations between GDM and alterations in the maternal oral microbiome. While these findings imply a correlation between GDM and oral microbial changes, causality cannot be directly inferred. Further research is warranted to decipher the underlying mechanisms driving these associations and to explore their potential implications for maternal oral health and pregnancy outcomes. Nonetheless, the insights gleaned from this review underscore the importance of integrating oral health assessments into routine prenatal care protocols for gestational diabetic individuals. By doing so, healthcare providers can enhance risk stratification, early detection, and management of GDM, ultimately improving maternal and neonatal health outcomes.

Keywords: Gestational Diabetes Mellitus, Pregnancy, Oral Microbiome

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INTRODUCTION

Rationale

The intersection of gestational diabetes mellitus (GDM), maternal oral health, and the oral microbiome represents a complex yet relatively underexplored area within the field of maternal and oral health. While existing research has highlighted the adverse effects of GDM on both maternal and fetal outcomes, including increased risks of preeclampsia, macrosomia, and neonatal hypoglycemia, limited attention has been given to its potential impact on maternal oral health and the oral microbiome. Given the well-established link between oral health and systemic health, particularly during pregnancy, there is a pressing need to comprehensively understand how GDM may influence maternal oral health and the composition of the oral microbiome.

Recent studies have emphasized the bidirectional relationship between oral health and systemic health, elucidating how oral pathogens and inflammatory mediators can disseminate systemically, potentially exacerbating conditions such as cardiovascular disease, diabetes, and adverse pregnancy outcomes (Atarashi et al., 2017; Bui et al., 2019; Perez-Chaparro et al., 2014). Within this context, the oral microbiome serves as a dynamic ecosystem that plays a crucial role in maintaining oral homeostasis and modulating host immune responses (Dewhirst et al., 2010; Lamont et al., 2018). Perturbations in the oral microbiota composition, often associated with conditions like periodontal disease and dental caries, have been linked to systemic inflammation and metabolic dysregulation (Bui et al., 2019). However, while considerable attention has been directed towards understanding the impact of maternal oral health on pregnancy outcomes, such as preterm birth and low birth weight, the influence of gestational diabetes mellitus (GDM) on

maternal oral health and the oral microbiome remains relatively understudied (Kumar et al., 2011). Addressing this gap is imperative, as GDM poses significant health risks to both mothers and infants, and understanding its potential effects on the oral microbiome could offer novel insights into preventive and therapeutic strategies for improving maternal and neonatal health during pregnancy (Bui et al., 2019). By unraveling the complex interrelationship between GDM, maternal oral health, and the oral microbiome, researchers can pave the way for more targeted interventions aimed at mitigating adverse pregnancy outcomes and promoting overall maternal and infant well-being.

Moreover, the dynamic nature of the oral microbiome during pregnancy and its potential modulation by systemic conditions like GDM underscore the importance of conducting a scoping review to explore the breadth and depth of available literature. By adopting a scoping review approach, is allowed for systematic mapping of the existing research landscape, identification of gaps in knowledge, and illustration of key concepts and definitions pertinent to the research topic. This approach allowed for a comprehensive examination of diverse study designs, methodologies, and findings, providing a holistic understanding of the current state of research on the impact of GDM on maternal oral health and the oral microbiome. Additionally, the scoping review methodology is well-suited to address the broad yet interconnected research questions surrounding this multifaceted topic, facilitating the identification of priority areas for future investigation and intervention.

In this scoping review, our primary objective was to comprehensively synthesize existing literature concerning the intersection of gestational diabetes mellitus (GDM), maternal oral health, and the oral microbiome among pregnant women. By mapping the available research

landscape, we aimed to evaluate the current understanding of how GDM may influence maternal oral health and the composition of the oral microbiome, as well as identify gaps in knowledge and potential avenues for future research. Through this review, we sought to provide insights into the complex interplay between GDM, maternal oral health, and the oral microbiome, thereby informing clinical practice, public health initiatives, and research priorities.

Furthermore, despite the growing recognition of the relationship between gestational diabetes mellitus (GDM) and maternal oral health, there are notable gaps in the existing literature that warrant attention. One such gap lies in the limited exploration of potential mechanistic pathways linking GDM to alterations in the oral microbiome during pregnancy. While observational studies have provided valuable insights into the association between GDM and oral microbial changes, mechanistic studies elucidating the underlying biological mechanisms are scarce. Understanding these mechanisms is essential for establishing causal relationships and developing targeted interventions to mitigate adverse outcomes associated with GDM.

Additionally, there is a paucity of research examining the long-term implications of GDM-associated oral microbial alterations on maternal and child health beyond the immediate perinatal period. Longitudinal studies tracking the trajectory of oral microbiome changes over time in GDM-affected individuals and their offspring are needed to assess the persistence of microbial dysbiosis and its impact on oral and systemic health outcomes. Moreover, many existing studies have focused on exploring associations between GDM and oral health outcomes in high-income countries, with limited representation from low- and middle-income countries. Given the disparities in healthcare access, oral health practices, and prevalence of GDM across different socioeconomic settings, there is a critical need for research that encompasses diverse populations

to ensure the generalizability and applicability of findings on a global scale. Addressing these gaps in the literature will not only advance our understanding of the complex interplay between GDM, maternal oral health, and the oral microbiome but also inform evidence-based strategies for preventive care and intervention in at-risk populations.

Moving forward, future studies should employ longitudinal designs to elucidate temporal associations and causality between GDM, oral health outcomes, and oral microbial changes. Mechanistic investigations using experimental models and advanced molecular techniques can help unravel the underlying biological pathways linking GDM to alterations in the oral microbiome. Furthermore, there is a need for studies encompassing diverse populations, including those from low- and middle-income countries, to ensure the generalizability and applicability of findings across different socio-economic contexts. Integrating multi-omics approaches, such as metagenomics and metabolomics, can provide a deeper understanding of microbial-host interactions and identify potential biomarkers for GDM-related oral health complications. Additionally, interventional studies evaluating the effectiveness of targeted oral health interventions in GDM-affected individuals are warranted to guide evidence-based preventive strategies and clinical management protocols. By addressing these recommendations, future research endeavors can advance our knowledge of the complex relationships between GDM, maternal oral health, and the oral microbiome, leading to improved maternal and neonatal health outcomes.

REVIEW OF THE LITERATURE

Recent Advances in Oral Microbiome Research and its Systemic Health Implications

Our comprehension of the oral microbiome, the diverse community of microorganisms inhabiting the oral cavity, has undergone significant refinement in recent years, primarily due to advancements in sequencing technologies and analytical methodologies tailored to oral microbial ecosystems (Perez-Chaparro et al., 2014). Historically, early studies of oral microbiology primarily relied on culture-based techniques, which offered limited insight into the complexity and diversity of oral microbial communities. However, with the advent of high-throughput sequencing approaches, such as 16S rRNA gene sequencing and metagenomic sequencing, researchers have been able to characterize the oral microbiome with unprecedented depth and granularity (Kumar et al., 2011).

The oral microbiome plays a pivotal role in maintaining oral health and has been linked to the development and progression of various oral diseases, including dental caries, periodontal diseases, and oral infections (Zarco et al., 2012). Research has revealed correlations between the oral microbiome and host factors, such as immune responses, salivary composition, and oral epithelial cell function, in shaping oral microbial ecology and maintaining oral homeostasis (Gümüş et al., 2015). For example, dysbiosis within the oral microbiome, characterized by shifts in microbial composition and function, has been implicated in the pathogenesis of periodontal diseases, where the dysregulated host-microbe interactions contribute to inflammation, tissue destruction, and eventual tooth loss (Bui et al., 2019).

Moreover, existing evidence suggests that the oral microbiome extends its influence beyond the oral cavity, with potential implications for systemic health (Atarashi et al., 2017). Associations have been identified between oral microbial profiles and systemic conditions such as cardiovascular diseases, diabetes, and respiratory infections, highlighting the interconnectedness between oral health and overall health (Tonetti et al., 2018). For instance, periodontal pathogens and inflammatory mediators originating from the oral cavity can enter the bloodstream and trigger systemic inflammatory responses, potentially exacerbating existing systemic conditions or predisposing individuals to systemic diseases (Tonetti et al., 2018).

Despite these advancements, there remain significant gaps in our understanding of the oral microbiome and its implications for systemic health (Perez-Chaparro et al., 2014). The complexity and dynamic nature of oral microbial communities, influenced by factors such as oral hygiene practices, diet, smoking, and host genetics, present challenges in deciphering the underlying mechanisms driving oral health and disease. Additionally, the role of the oral microbiome in the etiology of systemic diseases requires further investigation through longitudinal studies and mechanistic research to delineate causative relationships and therapeutic targets.

Gestational Diabetes Mellitus and the Oral Microbiome

Gestational Diabetes Mellitus (GDM) is a prevalent complication during pregnancy, affecting up to 10% of pregnant women worldwide (American Diabetes Association, 2024). Characterized by glucose intolerance with onset or first recognition during pregnancy, GDM, if not properly managed, can lead to adverse outcomes for both the mother and the offspring (The HAPO Study

Cooperative Research Group, 2008). While extensive research has unveiled the association between GDM and various systemic health issues, recent investigations have begun to uncover its potential implications for oral health, particularly in relation to the oral microbiome.

The oral microbiome, comprising diverse microbial communities inhabiting the oral cavity, plays a crucial role in maintaining oral health and has been increasingly recognized for its influence on systemic well-being (Dewhirst et al., 2010). Studies exploring the association between GDM and the oral microbiome have revealed intriguing associations, suggesting potential implications for both maternal oral health and pregnancy outcomes.

Research has shown alterations in the oral microbial composition and diversity among women with GDM compared to healthy pregnant individuals (Gupta et al., 2017). Specifically, GDM has been associated with shifts in the abundance of certain bacterial taxa, including an increase in potentially pathogenic species and a decrease in beneficial microbes (Corrêa et al., 2023). These dysbiotic changes in the oral microbiome may contribute to the development of oral health complications, such as periodontal disease and dental caries, which have been linked to adverse pregnancy outcomes (Ide et al., 2013).

Furthermore, the oral microbiome's dysregulation in GDM may extend beyond local oral health implications, potentially exerting systemic effects. Disruptions in the oral microbial ecology have been proposed to contribute to systemic inflammation and metabolic dysregulation, both of which are implicated in the pathophysiology of GDM and its associated complications (Kassebaum et al., 2017). Additionally, there is evidence suggesting a bidirectional relationship

between oral health and glycemic control, with poor oral health potentially exacerbating glycemic control issues in GDM, and vice versa (Negrato et al., 2013).

Despite these findings, further research is warranted to elucidate the mechanistic underpinnings of the relationship between GDM and the oral microbiome, as well as its clinical implications. Longitudinal studies are needed to establish temporal associations and determine causality, while mechanistic investigations can provide insights into the molecular pathways linking GDM, oral dysbiosis, and adverse pregnancy outcomes.

Moreover, while the association between GDM and systemic health issues is well-established, recent research has begun to uncover its potential impact on the oral microbiome and maternal oral health. Understanding the complex interplay between GDM and the oral microbiome may offer new avenues for preventive and therapeutic interventions to improve both maternal and offspring outcomes during pregnancy.

Oral Microbiome and Pregnancy

The interconnectivity between the oral microbiome and pregnancy is a multifaceted phenomenon with significant implications for maternal and fetal health. Hormonal fluctuations during pregnancy, particularly elevated levels of estrogen and progesterone, can exert profound effects on the oral microbiome, predisposing pregnant individuals to an increased risk of oral health issues (Xiong et al., 2009; Lin et al., 2007). These hormonal fluctuations create an environment conducive to the proliferation of pathogenic bacteria within the oral cavity, leading to dysbiosis (Lin et al., 2007). Dysbiosis, characterized by alterations in the microbial composition and

function, has been implicated in the development of common pregnancy-related oral health conditions such as gingivitis and periodontal disease (Carrillo-de-Albornoz et al., 2012).

Furthermore, the immune system undergoes adaptations during pregnancy to accommodate the growing fetus, resulting in alterations in immune responses within the oral cavity (Madianos et al., 2013). These immune changes can impact the host-microbiome interactions, potentially exacerbating inflammation and contributing to the progression of oral diseases (Silk et al., 2008). Additionally, dietary habits often undergo modifications during pregnancy, with potential implications for the oral microbiome composition (Giannella et al., 2023). The consumption of sugary foods and beverages, common during pregnancy, can provide substrates for acid-producing bacteria, leading to an increased risk of dental caries (Hwang et al., 2011).

Understanding the complex interactions between pregnancy and the oral microbiome is essential for promoting maternal and fetal health. Future research endeavors should focus on interpretation of the underlying mechanisms driving dysbiosis during pregnancy and exploring novel strategies for preventing and managing pregnancy-related oral health conditions.

Link Between GDM and Oral Health

Existing evidence suggests a bidirectional relationship between GDM and oral health. Several studies have reported a higher prevalence of periodontal disease and gingivitis in women with GDM compared to non-diabetic pregnant women (Abariga & Whitcomb, 2016). Furthermore, maternal periodontitis has been implicated as a potential risk factor for the development of GDM, indicating a possible relationship between oral health and glycemic control during pregnancy (Bendek et al., 2021). The microbial changes observed in the oral cavity of pregnant

women with GDM may serve as a potential biomarker for monitoring glycemic control and overall maternal health during pregnancy; however, the underlying mechanisms driving this association remain unclear.

Role of the Oral Microbiome in GDM

Recent research has focused on investigating the potential role of the oral microbiome in the pathogenesis of GDM. Studies have demonstrated alterations in the oral microbial composition of women with GDM compared to healthy controls, with an increase in the abundance of certain pathogenic species and a decrease in beneficial commensal bacteria (Corrêa et al., 2023). These dysbiotic changes may contribute to systemic inflammation and insulin resistance, exacerbating the metabolic disturbances associated with GDM (Corrêa et al., 2023).

There is growing recognition of the intricate relationship between GDM and the oral microbiome. Understanding the mechanisms underlying this association could have significant implications for both maternal and offspring health. Further research is warranted to elucidate the causal pathways linking GDM, oral dysbiosis, and adverse pregnancy outcomes, with the ultimate goal of developing targeted interventions to improve maternal glycemic control and oral health during pregnancy.

OBJECTIVES

This scoping review aimed to comprehensively map the existing literature concerning the association between oral microbiota composition between pregnant women with and without GDM, examine the correlation between changes in oral microbiota during pregnancy and GDM status, and assess the implications of maternal oral microbiota alterations on neonatal oral health outcomes within the context of GDM. Specifically, it seeked to explore several facets of this relationship. Firstly, the review endeavored to determine the prevalence of GDM among pregnant women in studies investigating its connection with alterations in the oral microbiome. Secondly, it aimed to identify the diverse methodologies employed in research endeavors focused on assessing the oral microbiome in pregnant women with GDM. Furthermore, the review aimed to delineate the primary outcomes reported in studies examining the oral microbiome in this demographic.

This review intended to depict variations in findings across different populations, settings, or study designs and seeks to pinpoint gaps in the current literature and areas necessitating further investigation to advance our comprehension of this intricate relationship. These objectives guideed the systematic synthesis of evidence, facilitating a comprehensive understanding of the interplay between GDM and the oral microbiome in pregnant women.

While progress has been made in unraveling the complexities of the oral microbiome, much remains to be discovered regarding its role in oral and systemic health. Continued research efforts aimed at analyzing the dynamic interactions between oral microbial communities and host

physiology hold promise for the development of preventive and therapeutic strategies to promote oral health and mitigate the risk of associated systemic diseases.

METHODOLOGY

Protocol

The protocol for this scoping review followed the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for Scoping Reviews (PRISMA-ScR). Developed in 2018, the PRISMA-ScR checklist provides a comprehensive framework consisting of 22 items explicitly tailored for scoping review processes. Adhering to this protocol ensured transparency, rigor, and consistency in the conduct and reporting of the scoping review methodology.

Eligibility Criteria

The study focused on investigating the impact of gestational diabetes mellitus (GDM) on maternal oral health outcomes, particularly examining the relationship with the maternal oral microbiome. Inclusion criteria encompassed research involving the maternal oral microbiome as a primary variable, with an inclusion of GDM status within pregnancy, pregnancy outcomes, and neonate status. A focus on human subjects only was set as a parameter for screening.

Publications must have been released between 2020 and 2024 and be available in English or have English translations accessible. Limiting the publication timeframe ensured that the study reflects the most current research landscape, incorporating recent developments, methodologies, and insights into the understanding of the relationship between gestational diabetes mellitus (GDM) and maternal oral health outcomes. By focusing on the most recent publications, the study provided up-to-date information that is relevant for informing clinical practice, policy decisions, and future research directions in this evolving field. Additionally, restricting the

timeframe helped maintain the study's feasibility and manageability by narrowing the scope of literature to be reviewed while still capturing contemporary evidence. There was no restrictions on study design, allowing for the inclusion of experimental, observational, and qualitative studies. However, all reviews were excluded from the results examined. Geographical location was not a limiting factor, and publications from any region were considered. Eligibility as determined based on keyword relevance in full-text articles, particularly focusing on "gestational diabetes mellitus," "pregnancy," and "oral microbiome."

Information Sources

To ensure comprehensive coverage of relevant literature, the search strategy for this scoping review was executed using PubMed and Web of Science electronic databases. Search strategies were refined independently for each database to optimize the retrieval of pertinent studies. The final search results from both databases were exported into EndNote for management and duplicate removal.

Search

The search strategy was conducted independently by the reviewer, employing a combination of relevant keywords related to gestational diabetes mellitus (GDM) and oral microbiome. Searches were conducted in two electronic databases, namely PubMed and Web of Science, with filters set to exclude reviews and limit publication dates to studies published between 2020 and 2024. This rigorous approach ensured the retrieval of recent and pertinent studies focusing on the association between GDM and maternal oral microbiome composition and diversity.

PubMed

- "Gestational diabetes AND oral microbiome NOT review"
    - 31 results
- "Gestational diabetes AND pregnancy AND oral microbiome NOT review"
    - 29 results
- "Gestational diabetes AND pregnancy AND oral bacteria NOT review"
    - 32 results

Web of Science

- "Gestational diabetes AND oral microbiome NOT review"
    - 15 results
- "Gestational diabetes AND pregnancy AND oral microbiome NOT review"
    - 10 results
- "Gestational diabetes AND pregnancy AND oral bacteria NOT review"
    - 11 results

Selection of Sources of Evidence

The selection process involved screening articles individually by title, abstract, and full text. A total of 128 articles were initially identified through the search parameters. Subsequently, using the EndNote Windows application, duplicates were targeted and removed, leaving 48 unique articles for evaluation. These articles were fully accessible and underwent a thorough screening process to ensure alignment with the predetermined inclusion criteria. Specifically, articles focusing on the oral microbiome were retained, while many with a primary focus on the gut

microbiome were excluded. Following this rigorous screening process, a final count of 8 articles were included for synthesis and analysis in this scoping review.

Data Charting Process

The data charting process was conducted independently by the reviewer. EndNote 21 was utilized for managing bibliographic information, while Excel and handwritten notes were utilized to compile the characteristics of available data extracted from the identified studies. This method allowed for systematic organization and analysis of key data points relevant to the objectives of the scoping review.

Data Items

Periodontal Health:

- Definition: Refers to the state of health or disease of the tissues supporting the teeth, including the gums, periodontal ligament, and alveolar bone.
- Measurement: Assessed through various clinical parameters such as probing depth, clinical attachment loss, bleeding on probing, and presence of periodontal pathogens.

Gestational Diabetes Mellitus (GDM):

- Definition: Diabetes first diagnosed during pregnancy, characterized by high blood sugar levels.
- Measurement: Diagnosis confirmed through blood glucose testing, including fasting plasma glucose, oral glucose tolerance test, or hemoglobin A1c levels.

Oral Microbiota:

- Definition: The microbial community residing within the oral cavity.
- Measurement: Analyzed using various techniques such as high-throughput sequencing, culture-based methods, or molecular assays to identify specific microbial taxa and their relative abundances.

Pregnancy Outcomes:

- Definition: Refers to the health outcomes for both the mother and the offspring during and after pregnancy.
- Measurement: Includes variables such as preterm birth, low birth weight, macrosomia, preeclampsia, and other complications related to gestational diabetes.

Maternal Health Indicators:

- Definition: Health indicators specific to the pregnant mother.
- Measurement: Includes variables such as maternal age, pre-pregnancy BMI, parity, smoking status, and socioeconomic status.

Infant Health:

- Definition: Health outcomes and indicators specific to the newborn.
- Measurement: Includes variables such as birth weight, gestational age at birth, APGAR scores, and neonatal complications.

Salivary Biomarkers:

- Definition: Biomolecules present in saliva that can serve as indicators of health or disease.
- Measurement: Assessed through salivary analysis for specific biomarkers related to inflammation, immune response, or microbial activity.

Synthesis of Results

The synthesis of results in this scoping review involved utilizing tables to present the findings obtained from the screening process. Specifically, the "Identification of Studies via Databases" chart, as provided by the PRISMA guidelines, was employed to showcase the screening and selection process of articles. Additionally, other tables were utilized to present qualitative results, facilitating the grouping of articles based on thematic analysis and key findings, thereby offering a comprehensive overview of the literature landscape surrounding the relationship between oral microbiome and gestational diabetes mellitus.

RESULTS

Selection of Sources of Evidence

The process of source selection is delineated in the table below, adhering to guidelines outlined on the PRISMA-ScR website.

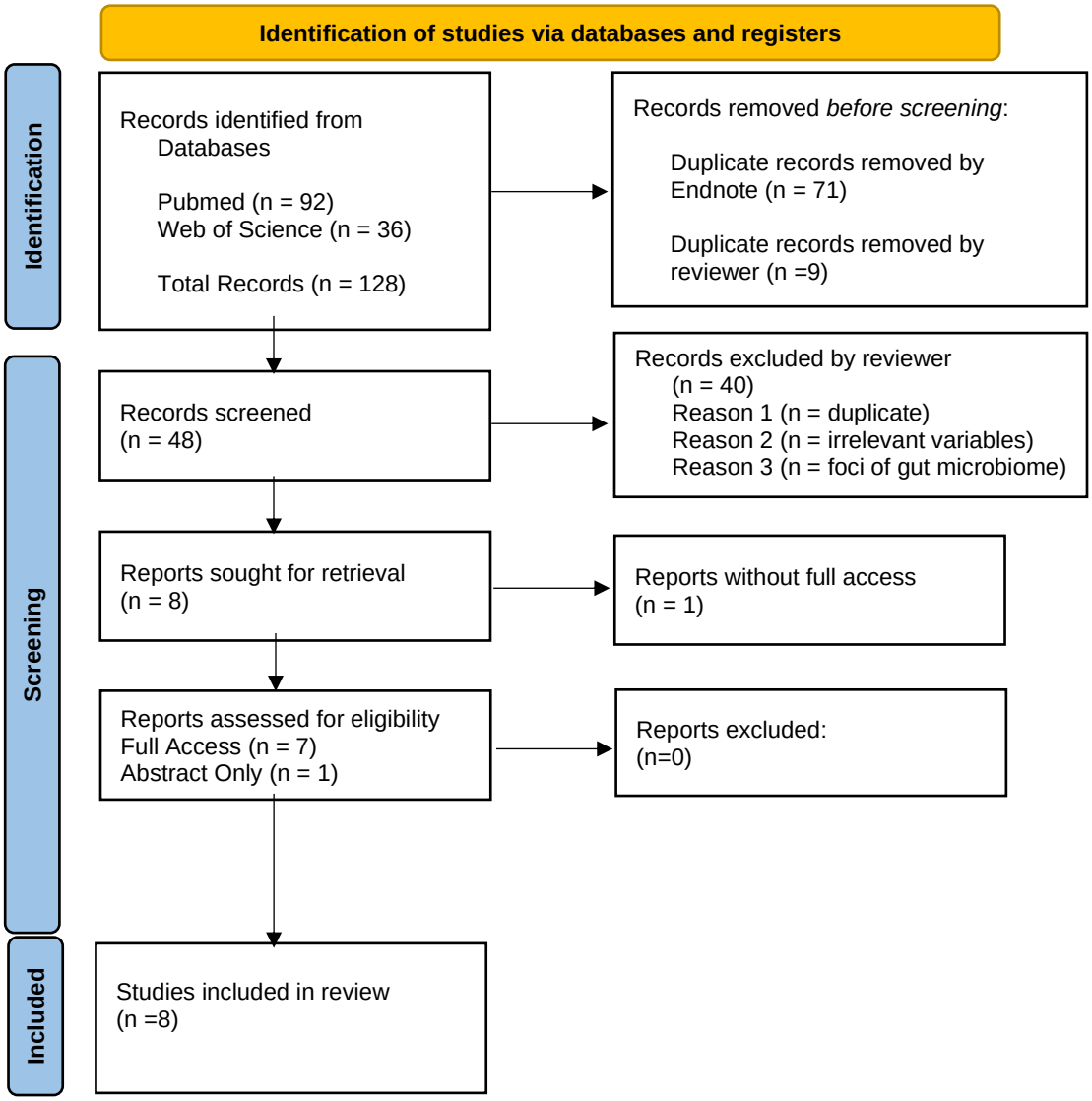

FIGURE 1: IDENTIFICATION OF STUDIES VIA DATABASES AND REGISTERS

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

Characteristics of Sources of Evidence

Information regarding the sources of evidence encompassed details such as the source type, methodology, participant demographics, outcomes assessed, results obtained, and conclusions drawn. Limitations to full source information were restricted in abstract-only articles. To facilitate information retrieval, tables were be utilized for presentation purposes.

TABLE 1
STUDY DESIGNS UTILIZED IN EIGHT PRIMARY STUDIES

Study Design	Total
Cross-Sectional	2
Case-Control	1
Cohort	5
Randomized Controlled Trials	0

TABLE 2
OVERVIEW OF EIGHT PRIMARY STUDIES EVALUATING GESTATIONAL DIABETES, MICROBIOMES, AND PREGNANCY OUTCOMES

Author	Title	Year	Design	Sample Size	Country of Origin	Abstract or Full Access
Choudhury, P, et al.	Microorganisms of maternal periodontitis cause adverse pregnancy outcomes in gestational diabetic individuals: a preliminary observational report	2022	Prospective Cohort	60	Unknown	Abstract Only
Crusell, M. K. W, et al.	Gestational diabetes and the human salivary microbiota: a longitudinal study during pregnancy and postpartum	2020	Prospective Cohort	213	Denmark	Full Access
Li, X. Q, et al.	The oral microbiome of pregnant women facilitates gestational diabetes discrimination	2021	Cross-Sectional	111	China	Full Access
Singh, P, et al.	Evaluation of effect of gestational diabetes mellitus on composition of the initial oral microbiota of neonates	2020	Cross-Sectional	155	India	Full Access
Song, Q, et al.	Influences of gestational diabetes mellitus on the oral microbiota in offspring from birth to 1 month old	2022	Prospective Cohort	54	China	Full Access
Susic, D, et al.	Microbiome Understanding in Maternity Study (MUMS), an Australian prospective longitudinal cohort study of maternal and infant microbiota: study protocol	2020	Prospective Cohort	200	Australia	Full Access
Xu, Y, et al.	Differential intestinal and oral microbiota features associated with gestational diabetes and maternal inflammation	2020	Case-Control	61	China	Full Access
Zhang, X, et al.	Differences in the oral and intestinal microbiotas in pregnant women varying in periodontitis and gestational diabetes mellitus conditions	2021	Prospective Cohort	69	China	Full Access

TABLE 3
METHODOLOGIES AND UNIQUE STUDY CHARACTERISTICS OF EIGHT PRIMARY STUDIES

Author	Scales and Tools	Methodology	Unique Information	Findings
Choudhury, P, et al.	Periodontal health assessment tools (e.g., probing depth, clinical attachment loss)	Clinical assessments conducted by trained periodontists; Periodontal health measured using standardized protocols such as the Community Periodontal Index of Treatment Needs (CPITN)	Investigated the impact of periodontal health on adverse pregnancy outcomes in gestational diabetic individuals	Found a significant correlation between severity of periodontal disease and adverse pregnancy outcomes in gestational diabetic individuals
Crusell, M. K. W, et al.	High-throughput sequencing techniques for salivary microbiota analysis	Salivary samples collected at multiple time points during pregnancy and postpartum; Microbial composition analyzed using Illumina sequencing platforms; Diversity indices calculated based on sequencing data	Examined longitudinal changes in the salivary microbiota of pregnant women with and without gestational diabetes	Identified significant alterations in salivary microbiota composition in women with gestational diabetes compared to healthy controls
Li, X. Q, et al.	Bioinformatics tools for microbial composition analysis	Oral microbiome characterized using 16S rRNA gene sequencing; Bioinformatics tools employed for taxonomic classification and diversity analysis	Developed a discriminatory model based on oral microbiome composition for gestational diabetes discrimination	Established a predictive model for gestational diabetes based on oral microbiome composition.
Singh, P, et al.	Culture-based techniques or high-throughput sequencing for neonatal oral microbiota analysis	Oral swabs collected from neonates shortly after birth; Microbial composition analyzed using culture-based techniques or high-throughput sequencing	Investigated the impact of maternal gestational diabetes on the initial oral microbiota colonization of neonates	Found a higher abundance of potentially pathogenic bacteria in the oral microbiota of neonates born to mothers with gestational diabetes compared to controls
Song, Q, et al.	High-throughput sequencing for oral microbiota analysis in offspring	Oral swabs collected from offspring at birth and one month postpartum; Microbial composition analyzed using high-throughput sequencing techniques	Explored longitudinal changes in the oral microbiota of offspring born to mothers with gestational diabetes	Identified a gradual shift in oral microbiota composition from birth to one month postpartum in offspring of mothers with gestational diabetes
Susic, D, et al.	Comprehensive survey covering demographics, medical history, dietary habits, and oral hygiene. Infant Questionnaire collects data on infant health, feeding patterns, and antibiotic use. Oral Microbiota Sampling Kit. DNA Extraction and Sequencing: Utilizes high-throughput sequencing for analysis.	Prospective Longitudinal Cohort Study Design. Tracks changes in oral microbiota over time. Participant recruitment from antenatal clinics and maternity hospitals. Follow-Up Visits scheduled during pregnancy and postpartum periods for additional sampling. Statistical Analysis employs multivariate analysis and regression modeling.	Prospective longitudinal cohort study protocol examining maternal and infant microbiota in Australia	Outlined the methodology for a prospective longitudinal cohort study examining maternal and infant microbiota in Australia, including sampling procedures, data collection methods, and follow-up protocols
Xu, Y, et al.	High-throughput sequencing for intestinal and oral microbiota analysis	Fecal and oral samples collected from pregnant women; Microbial composition analyzed using high-throughput sequencing; Inflammatory markers assessed in maternal serum	Investigated differential features of intestinal and oral microbiotas associated with gestational diabetes and maternal inflammation	Found distinct microbial signatures in the intestinal and oral microbiotas of pregnant women with gestational diabetes compared to controls
Zhang, X, et al.	Periodontal health assessment tools; high-throughput sequencing for oral and intestinal microbiota analysis	Periodontal health assessed using clinical measures; Oral and intestinal microbiota characterized using high-throughput sequencing techniques	Explored differences in the oral and intestinal microbiotas among pregnant women varying in periodontitis and gestational diabetes mellitus conditions	Identified significant associations between periodontal health status, oral microbiota composition, and gestational diabetes mellitus severity.

TABLE 4
STUDY OBJECTIVES OF EIGHT PRIMARY STUDIES EVALUATING GESTATIONAL DIABETES, MICROBIOMES, AND PREGNANCY OUTCOMES

Title	Objective
Microorganisms of maternal periodontitis cause adverse pregnancy outcomes in gestational diabetic individuals: a preliminary observational report	To evaluate the association of Fusobacterium nucleatum and Capnocytophaga species in dental plaque, cord blood, pericrevicular vaginal samples, and adverse pregnancy outcomes in gestational diabetic mellitus (GDM) women with and without periodontitis stage II.
Gestational diabetes and the human salivary microbiota: a longitudinal study during pregnancy and postpartum	Investigate whether gestational diabetes mellitus (GDM) is linked to variations in the composition and diversity of the salivary microbiota during pregnancy and postpartum
The oral microbiome of pregnant women facilitates gestational diabetes discrimination	Identify biomarkers from the oral microbiota that can effectively discriminate between pregnant women with GDM and those without GDM and explore the possible relationships between GDM and two major oral diseases, dental caries and chronic periodontitis
Evaluation of effect of gestational diabetes mellitus on composition of the initial oral microbiota of neonates	Investigate potential differences in the oral microbiota of neonates born to mothers with GDM compared to those born to nondiabetic mothers
Influences of gestational diabetes mellitus on the oral microbiota in offspring from birth to 1 month old	Investigate the influence of maternal gestational diabetes mellitus (GDM) on the oral microbiota of newborns and whether any differences persist up to one month of age. Explore potential differences in metabolic functional pathways and microbial ecological networks between the GDM and non-GDM groups.
Microbiome Understanding in Maternity Study (MUMS), an Australian prospective longitudinal cohort study of maternal and infant microbiota: study protocol	Comprehensively investigate the microbiome throughout pregnancy and its evolution during the first year of life, focusing on both maternal and infant microbiota
Differential intestinal and oral microbiota features associated with gestational diabetes and maternal inflammation	Analyze the association between gestational diabetes mellitus (GDM) and the microbiota composition of pregnant women, specifically focusing on the intestinal and oral microbiota during the third trimester of pregnancy.
Differences in the oral and intestinal microbiotas in pregnant women varying in periodontitis and gestational diabetes mellitus conditions	Examine the potential association between oral and intestinal microbiotas of pregnant women with periodontitis and/or gestational diabetes mellitus (GDM) in the second trimester.

TABLE 5
INDIVIDUAL MICROBIOTA IDENTIFIED IN EIGHT PRIMARY STUDIES EVALUATING MATERNAL AND NEONATAL MICROBIOMES

Title	Microbial Species Identified
Microorganisms of maternal periodontitis cause adverse pregnancy outcomes in gestational diabetic individuals: a preliminary observational report	Fusobacterium nucleatum and Fusobacterium
Gestational diabetes and the human salivary microbiota: a longitudinal study during pregnancy and postpartum	Firmicutes, Bacteroidetes, Proteobacteria, Prevotella, Veillonella, Streptococcus, Haemophilus, Actinobacillus paraheamolyticus, Neisseria, Treponema, Alloscardovia, Dialister, Filifactor, Parvimonas, Atopobium, Corynebacterium, Peptostreptococcus, Bulleidia, Bacteriodales, Leptotrichia, and Weeksellaceae
The oral microbiome of pregnant women facilitates gestational diabetes discrimination	Lautropia, Neisseria, Streptococcus, Veillonella, Streptococcus , Neisseriales, Selenomonas, and Leptotrichia
Evaluation of effect of gestational diabetes mellitus on composition of the initial oral microbiota of neonates	Firmicutes, Actinobacteria, Bacteroidetes, Proteobacteria, Tenericutes, Prevotella, Bacteroidetes, Bifidobacterium, Corynebacterium, Ureaplasma, and Weissella
Influences of gestational diabetes mellitus on the oral microbiota in offspring from birth to 1 month old	Actinobacteria, Bacteroidetes, Firmicutes, and Proteobacteria
Microbiome Understanding in Maternity Study (MUMS), an Australian prospective longitudinal cohort study of maternal and infant microbiota: study protocol	N/A
Differential intestinal and oral microbiota features associated with gestational diabetes and maternal inflammation	**Intestinal:** Bacteroides, Bifidobacterium, Blautia, Coprococcus, and Faecalibacterium **Oral:** Leptotrichia, Neisseria, Porphyromonas, Prevotella, Streptococcus, and Veillonella
Differences in the oral and intestinal microbiotas in pregnant women varying in periodontitis and gestational diabetes mellitus conditions	Proteobacteria, Firmicutes, Actinobacteria, and Bacteroidetes, Spirochaetes, Tenericutes and Synergistetes

TABLE 6
STUDY REFERENCE NUMBERS FOR RESULTS TABLE

Study Number	Title
1	Microorganisms of maternal periodontitis cause adverse pregnancy outcomes in gestational diabetic individuals: a preliminary observational report
2	Gestational diabetes and the human salivary microbiota: a longitudinal study during pregnancy and postpartum
3	The oral microbiome of pregnant women facilitates gestational diabetes discrimination
4	Evaluation of effect of gestational diabetes mellitus on composition of the initial oral microbiota of neonates
5	Influences of gestational diabetes mellitus on the oral microbiota in offspring from birth to 1 month old
6	Microbiome Understanding in Maternity Study (MUMS), an Australian prospective longitudinal cohort study of maternal and infant microbiota: study protocol
7	Differential intestinal and oral microbiota features associated with gestational diabetes and maternal inflammation
8	Differences in the oral and intestinal microbiotas in pregnant women varying in periodontitis and gestational diabetes mellitus conditions

TABLE 7

RESULTS AND FINDINGS OF EIGHT PRIMARY STUDIES EVALUATING GESTATIONAL DIABETES, MICROBIOMES, AND PREGNANCY OUTCOMES

Study Number	Results
1	•Incidence of adverse pregnancy outcomes was significantly higher in the GDM with periodontitis group (48%) than the nonperiodontitis GDM group (14%) with P < .07. •A moderate positive correlation (r = 0.429) between Gingival Index and HbA1c and microorganisms in the three samples at parturition. Macrosomia was seen in equal percentages in both groups. •Concomitant existence of F. nucleatum and Capnocytophaga species in all three samples was shown to be associated with increased incidence of adverse pregnancy outcomes in the GDM with periodontitis group. Of the adverse outcomes, preterm birth and low birth weight were more closely related to the periodontitis group than
2	•GDM is associated with a minor aberration of the salivary microbiota during late pregnancy and postpartum, and the composition of the salivary microbiota in women with GDM has similarities with salivary microbiota composition found in non-pregnant adults with type 2 diabetes. •In the third trimester, two species-level operational taxonomic units (OTUs), while eight OTUs postpartum were differentially abundant in women with GDM compared with normoglycaemic women. •Strong confounding effect of pre-pregnancy BMI indicating that body composition has an effect on the composition of salivary microbiota.
3	•Both saliva and dental plaque samples from pregnant women with GDM showed significant differences in microbial composition compared to those without GDM. •While there was no significant difference in microbial diversity, the microbial community composition was notably distinct in GDM patients. •The oral microbiome of GDM patients was found to be more similar to that of individuals with healthy periodontal status than those with periodontitis.
4	•There was increased bacterial microbiota in neonates born to mothers with GDM as compared to neonates born to nondiabetic mothers.
5	•Maternal GDM was associated with different colonization of oral microbiota in neonates, although the distinct difference between GDM and non-GDM groups diminished in infancy. •The oral microbiota structure, composition, functions, and ecological networks changed dramatically over time, regardless of GDM or non-GDM group.
6	N/A
7	•Intestinal and oral microorganisms in pregnant women are closely related to the status of GDM in the third trimester of pregnancy •GDM cases showed significant differences in β-diversity and increased Gammaproteobacteria and Hemophilus in intestinal microbiota.
8	•A close relationship between the oral microbiota and pregnant periodontitis was shown. Significant changes occur in both the oral and intestinal microbiomes when periodontitis was coupled with GDM. A separate influence of periodontitis and GDM on the oral and intestinal microbiotas may be indicated. •Periodontitis alone significantly decreased the oral microbial diversity (by Shannon index, p = 0.003) and changed the structure of the oral microbial community (by AMOVA, p 0.001). •GDM alone significantly increased the oral microbial diversity (by Shannon index, p = 0.049), and when combined with periodontitis, GDM significantly decreased the intestinal microbial richness (by observed species,

Synthesis of Results

In this scoping review, we systematically examined a collection of eight primary studies that investigated the interaction between gestational diabetes mellitus (GDM) and the oral microbiota among pregnant women. The studies employed a range of methodologies, including observational reports, longitudinal analyses, and cohort studies, to explore various dimensions of this relationship. Sample sizes ranged from 54-213 with a geographical focus primarily in China. No studies originated from the United States, which holds its own unique standards for quality of care, medical training, and research protocols which can influence the generalizability of the findings solely based off the numerous variables within the context of global standards.

Among the studies reviewed, Choudhury (2022) utilized observational methods to uncover how microorganisms associated with maternal periodontitis may contribute to adverse pregnancy outcomes in gestational diabetic individuals. The occurrence of negative outcomes during pregnancy was markedly greater in the group of pregnant individuals with gestational diabetes mellitus (GDM) who also had periodontitis, compared to those with GDM but without periodontitis. There was a moderately strong positive correlation observed between the measures of gum health with gingival index and blood sugar control via HbA1c levels, as well as with the presence of microorganisms at the time of childbirth. The frequency of babies born with a high birth weight, known as macrosomia, was similar in both groups. In summary, the simultaneous presence of F. nucleatum and Capnocytophaga species across all three sampled instances was linked to a higher rate of negative pregnancy outcomes in those with both GDM and periodontitis. Among these outcomes, the occurrence of preterm birth and low birth weight was

more frequently associated with the group suffering from periodontitis than with the incidence of macrosomia.

Another longitudinal study, Crusell (2020) tracked changes in the salivary microbiota throughout pregnancy and postpartum, employing sequencing techniques to discern alterations over time. During the last trimester, women with gestational diabetes mellitus (GDM) exhibited differences in two specific microbial populations in their saliva compared to women with normal blood sugar levels, and this discrepancy increased to eight distinct populations postpartum. Regardless of whether the women had GDM, there was a general decrease in the variety and evenness of these microbial populations from the later stages of pregnancy to nine months after giving birth. In summary, GDM corresponds to slight changes in the composition of saliva-based microbial communities during the latter part of pregnancy and the postpartum period. The overall reduction in the diversity of these communities post-delivery could potentially be linked to the immune system's natural adjustments throughout pregnancy, although the precise causes remain unclear.

Furthermore, a novel approach was undertaken to discriminate GDM based on the oral microbiome composition of pregnant women, employing advanced bioinformatics tools and discriminatory analyses. In this study, Li (2021) analyzed the oral microbiome of pregnant women, comparing those with gestational diabetes mellitus (GDM) to healthy controls. It identified significant differences in bacterial composition, particularly in saliva and dental plaque samples, between the two groups. Specific bacteria such as Lautropia, Neisseria, Streptococcus, and Veillonella were found to be associated with GDM. Classification models based on these bacterial biomarkers, especially when combined with clinical features like weight gain during pregnancy, demonstrated high accuracy in discriminating between GDM patients and healthy

pregnant women. These results suggest that oral microbiota could serve as promising noninvasive biomarkers for GDM detection.

Additionally, several studies delved into the neonatal implications of GDM on the oral microbiota, evaluating the effect of maternal GDM on the initial oral microbial composition of neonates and exploring longitudinal changes in the oral microbiota of offspring from birth to one month old. The first study, Singh (2020) assessed the effect of GDM on the initial oral microbiota composition of newborns born to mothers diagnosed with GDM and nondiabetic mothers. Results showed significant differences in the composition of oral microbiota between the two groups. Neonates born to mothers with GDM exhibited increased bacterial microbiota compared to those born to nondiabetic mothers. Major genera such as Prevotella, Bacteroidetes, Bifidobacterium, Corynebacterium, Ureaplasma, and Weissella differed significantly between the groups. The second study Song (2022) explored the oral microbiota of neonates born to mothers with and without GDM, examining whether differences persisted to 1 month of age. Oral samples were collected at birth and at an average age of one month from children of mothers with GDM and without GDM. While no significant differences were observed in diversity metrics, significant differences in taxonomic composition were found between the two groups. Specifically, the GDM group exhibited lower abundance of Veillonella at both "day one" and "day thirty" phases. Metabolic pathway analysis revealed enrichment of certain pathways in GDM subjects at the "day thirty" phase. Ecological network analysis also showed differences between GDM and non-GDM groups, with the non-GDM group containing more high-degree nodes and microbial interactions. Overall, both studies indicate that maternal GDM is associated with alterations in the oral microbial composition of neonates. These findings underscore the

importance of maternal GDM status in shaping the initial oral microbiota of offspring and highlight potential implications for neonatal health.

Furthermore, Xu (2020) examined the differential features of the intestinal and oral microbiotas associated with GDM and maternal inflammation, shedding light on potential biomarkers or indicators of GDM status. The study investigated how maternal microbiota might affect gestational diabetes mellitus. By analyzing the composition of gut and oral bacteria through 16S rRNA sequencing in the third trimester, researchers compared the microbiomes of women with GDM to those of women without the condition. Findings revealed that the diversity and composition of bacteria differed notably between the two groups. Specifically, women with GDM had a greater presence of Gammaproteobacteria and Hemophilus in their gut and higher levels of Selenomonas and Bifidobacterium but lower levels of Fusobacteria and Leptotrichia in their oral cavity. The study also utilized network analysis to examine the relationship between these microbiota, blood sugar levels, and inflammation. The study noted distinct microbial interaction patterns in women with GDM, which could suggest different microbial relationships in the presence of this condition. The study highlighted that the microbial populations in the intestines and mouth are linked with GDM status during late pregnancy and that these microbial characteristics could serve as noninvasive indicators for managing the health of pregnant women with GDM.

Lastly, Zhang (2021) explored the connection between the oral and gut microbiomes in pregnant women with periodontitis, gestational diabetes mellitus, both, or neither as a control group in the second trimester. Using 16S rRNA sequencing, researchers compared the diversity and composition of the oral and intestinal microbiotas across four different groups. The findings

showed that periodontitis alone significantly reduced the diversity of the oral microbiome and altered its composition. On the other hand, GDM alone increased the diversity of the oral microbiome. However, when periodontitis was present alongside GDM, there was a significant reduction in the diversity and richness of the intestinal microbiome, and the structure of the intestinal microbial community was affected. The analysis also identified specific microbial taxa that varied among the groups in both the oral and intestinal samples, but there were few consistent trends across the different conditions. Notably, the group with both periodontitis and GDM had the fewest types of bacteria shared between the oral and intestinal microbiotas. In summary, periodontitis had a marked impact on the oral microbiome in pregnant women, and the presence of GDM influenced both the oral and intestinal microbiomes. The study suggests that periodontitis and GDM might independently affect the microbiomes in different ways.

Each study employed distinct measures and tools tailored to its specific research questions and objectives. These included clinical assessments of periodontal health, molecular analyses of microbial communities using high-throughput sequencing technologies, and statistical models to discern associations and correlations.

The collective findings from these studies underscore the relationship between GDM and alterations in the oral microbiota during pregnancy. Specifically, they highlight potential biomarkers or indicators of GDM status within the oral microbiome, emphasizing the clinical relevance of understanding microbial dynamics in gestational diabetic individuals for improved maternal and neonatal health. While these findings provide compelling evidence of associations between gestational diabetes mellitus (GDM) and alterations in the oral microbiota, they could not directly conclude causal effects, thus emphasizing the need for further understanding of the

underlying pathways linking GDM and oral microbial changes. These insights hold implications for healthcare providers, policymakers, and researchers alike, urging further investigation into the mechanisms underpinning this complex correlation and its potential implications for clinical practice and public health initiatives.

DISCUSSION

Summary of Evidence

Summarizing evidence from eight primary studies reveals a discernible pattern highlighted the relationship between gestational diabetes mellitus (GDM) and oral microbiota alterations among pregnant women and neonates. Notably, these studies, employing diverse methodologies such as observational reports, longitudinal analyses, and cohort studies, collectively underscore significant associations between GDM and shifts in the composition and dynamics of the oral microbial community during pregnancy. Understanding the dynamic interplay between GDM and the oral microbiota holds promise for improving risk stratification, early detection, and management of gestational diabetes. Furthermore, leveraging these potential biomarkers within the oral microbiome could facilitate the development of targeted interventions aimed at mitigating adverse pregnancy outcomes associated with GDM, thereby enhancing overall maternal and neonatal health.

Specifically, findings from these investigations highlighted that individuals with gestational diabetes exhibited distinct oral microbial profiles compared to non-diabetic pregnant women. Notable alterations included shifts in microbial diversity, abundance, and composition, suggesting potential biomarkers or indicators of GDM status within the oral microbiome. Longitudinal studies tracking changes in the oral microbiota throughout pregnancy and postpartum are essential for elucidating the temporal dynamics of microbial communities and their implications for maternal and neonatal health over time. Furthermore, longitudinal analyses revealed dynamic changes in the oral microbiota throughout pregnancy and postpartum, with

distinct microbial signatures observed at different stages of gestation. Moreover, exploring the intergenerational transmission of microbiota from mother to infant could offer valuable insights into early-life determinants of health and disease risk, informing preventive measures and interventions to optimize neonatal health outcomes.

However, it is essential to note that while these findings suggest a correlation between GDM and oral microbial changes, direct causality cannot be inferred. The complexity of interactions between host factors, microbial communities, and environmental influences necessitates further elucidation of the underlying pathways driving these associations. Future research endeavors should prioritize investigating the mechanistic underpinnings of this relationship to delineate causal pathways and inform targeted interventions for gestational diabetic individuals.

Moreover, the implications of these findings extend beyond the realms of academia, bearing significance for healthcare providers, policymakers, and patients alike. Understanding the dynamic interplay between GDM and the oral microbiota holds promise for improving risk stratification, early detection, and management of gestational diabetes. By identifying potential biomarkers within the oral microbiome, clinicians may enhance diagnostic accuracy and tailor personalized interventions to mitigate adverse pregnancy outcomes associated with GDM.

In light of these insights, it becomes apparent that the synthesis of evidence from these studies not only addresses the original research questions and objectives but also provides actionable knowledge for relevant stakeholders. From guiding clinical decision-making to informing public health policies, the findings from this scoping review underscore the imperative of integrating oral health assessments into routine prenatal care protocols. By doing so, we can strive towards

improving maternal and neonatal health outcomes, thereby fulfilling the overarching goal of enhancing healthcare delivery and patient well-being.

Limitations

Several limitations must be acknowledged regarding the methodology and scope of this scoping review. Firstly, the screening process was conducted by a single reviewer, which may have introduced potential biases or overlooked relevant articles. Although efforts were made to adhere to the PRISMA-ScR guidelines, the absence of multiple reviewers may have impacted the comprehensiveness of the search and the accuracy of article selection.

Moreover, restricting the search to articles published within the last five years aimed to include the most recent data but may have limited the sample pool of relevant articles. This narrow timeframe may have excluded older studies that could have provided valuable historical context or insights into long-term trends in the relationship between gestational diabetes mellitus (GDM) and the oral microbiome.

Furthermore, the search was limited to only two databases, PubMed and Web of Science, potentially overlooking relevant studies indexed in other databases or published in non-indexed journals. Although these databases are widely recognized sources for biomedical literature, the exclusion of additional databases may have resulted in the omission of pertinent articles.

Another limitation arises from the fact that causal pathways linking GDM and the oral microbiome have yet to be fully elucidated. While this scoping review aims to map existing literature and identify patterns, the absence of established causal relationships limits the depth of analysis and interpretation of findings. Future research endeavors should prioritize mechanistic

investigations to address this knowledge gap and provide a more comprehensive understanding of the underlying pathophysiology. Variability in study quality, potential biases, and confounding factors within individual studies may impact the reliability and validity of the evidence synthesized. Additionally, one article included in this scoping review is currently ongoing, with the study protocol provided instead of finalized results. The notable absence of articles originating from the United States limits the generalizability of findings to populations with potentially different standards of care and dental practices. Considering the global relevance of the findings, it is important to acknowledge the potential influence of diverse healthcare systems and cultural practices on the generalizability of the findings and the applicability of interventions across different populations.

Deviation from the initial guidelines occurred when considering the primary variable studied, as some articles focused on the infant's microbiome instead of the mothers. While this broadened the scope of the search and provided insights into intergenerational microbial transmission, it also limited the initial search and introduced complexity in data synthesis and interpretation. Additionally, many initially searched items only addressed the gut microbiome and did not mention the oral microbiome, necessitating their exclusion. However, some studies addressed both the gut and oral microbiomes, highlighting the interconnectedness of microbial communities and systemic health.

Despite these limitations, this scoping review provides a comprehensive overview of the existing literature on the relationship between GDM and the oral microbiome. Recognizing these limitations is crucial for interpreting the findings and guiding future research directions in this evolving field. Addressing potential sources of bias and confounding factors, such as variations

in sample size and geographical focus, will be essential for ensuring the reliability and validity of future research findings in this area.

Conclusions

Moreover, this scoping review provides an overview of the relationship between gestational diabetes mellitus (GDM) and the oral microbiome in pregnant women. The synthesis of evidence reveals associations between GDM and alterations in the oral microbiota composition, suggesting potential implications for maternal and neonatal health. While highlighting key themes and methodologies, this review also identifies gaps in knowledge, guiding future research directions in this field.

The findings underscore the correlation between GDM and the oral microbiome during pregnancy, indicating dysbiotic changes that may contribute to systemic inflammation, metabolic dysregulation, and adverse pregnancy outcomes. Future research should focus on mechanistic investigations to decipher causal pathways, longitudinal studies to establish temporal associations, and interventional studies to evaluate therapeutic strategies. Interdisciplinary approaches that integrate insights from microbiology, immunology, and obstetrics will be instrumental in advancing our understanding of the complex interactions between GDM and the oral microbiota, paving the way for targeted interventions to improve maternal and neonatal health outcomes.

Furthermore, investigating the intergenerational transmission of microbiota and its implications for offspring health emerges as an important avenue for research. Despite limitations, this review

lays the groundwork for future studies aimed at advancing our understanding of this complex interaction and developing strategies to promote maternal and neonatal health during pregnancy.

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