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Review

The Effect of Diabetes Mellitus on Mandibular Growth

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Main Points

- Diabetes affects growth and development of the mandible.
- Impaired bone healing and formation affects orthodontic treatment in diabetic patients.
- More effective clinical strategies will help optimize patient orthodontic treatment outcomes.

ABSTRACT

Diabetes mellitus is a chronic condition characterized by insufficient insulin production or utilization. Affecting approximately 8.5% of adults globally, diabetes is categorized primarily into Type 1, Type 2, and gestational diabetes. Diabetes markedly impacts bone health, particularly affecting the growth and development of the mandible. Key alterations include impaired bone metabolism leading to diminished bone density and strength. Additionally, diabetes impairs bone healing processes, often exacerbated by deficiencies in vitamin D, thus increasing fracture risks. Understanding the interplay between diabetes and mandibular growth is essential for effective dental treatment planning and patient management. Importantly, the condition also alters essential growth factors and local blood supply to the mandibular region, compromising overall growth. Impaired bone healing and formation also affects orthodontic treatment in diabetic patients. Future research should prioritize longitudinal studies examining diabetes's long-term impact on mandibular development, exploring genetic predispositions and biomechanical properties. Understanding these mechanisms will facilitate more effective clinical strategies to mitigate the adverse effects of diabetes on bone health and optimize patient outcomes.

Keywords: Diabetes mellitus, bone metabolism, bone density, bone strength, healing, mandibular growth, genetic predisposition, clinical strategies

INTRODUCTION

Diabetes is a chronic condition that occurs when the pancreas does not produce enough insulin or when the body is unable to effectively utilize the insulin it produces. Insulin is a hormone crucial for regulating blood glucose levels.[1] The condition is characterized by hyperglycemia, which is persistently elevated blood glucose levels. There are several types of diabetes, including Type 1, Type 2, and gestational diabetes.[2] According to a study in 2017, around 8.5% of adults aged 18 and older were affected by diabetes, highlighting its prevalence and impact.[2] Diabetes can lead to serious health problems if not controlled, such as heart disease, nerve damage, eye issues, kidney failure, and amputations.[1] The mortality rates due to diabetes have shown an increase between 2000 and 2019, especially in lower-middle-income countries.[2] Symptoms of diabetes can vary and may include increased thirst, frequent urination, fatigue, blurred vision, unintentional weight loss, and more.[2] Diabetes

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management encompasses blood sugar monitoring, taking oral medications or insulin, following a healthy diet, engaging in physical activity, and maintaining a healthy lifestyle.[3] Managing blood sugar levels is crucial to prevent complications and improve overall well-being.[3] The prognosis for diabetes varies based on various factors like the type of diabetes, how well it is managed, age at diagnosis, presence of other health conditions, and the development of complications.[3] This review article will assess the effects of diabetes mellitus (DM) on bone metabolism and consequently the orthodontic tooth movement and mandibular growth, thereby elucidating the relationship between DM and orthodontic treatment.

Effect of Diabetes on Bone

According to scientific studies diabetes exerts significant effects on bone growth and development, impacting various aspects of bone health as follows:[4-6]

Altered bone metabolism: Diabetes, particularly type 2 DM disrupts bone metabolism by compromising bone cell function and matrix structure. This imbalance includes diminished osteoblast differentiation, increased osteoblast apoptosis, and enhanced osteoclast-mediated bone resorption, leading to impaired bone formation and turnover.[7]

Reduced trabecular bone mass: Diabetes affects trabecular bone mass negatively, contributing to decreased bone density and strength.[8]

Increased cortical bone mass: Interestingly, while trabecular bone mass is decreased, individuals with diabetes may experience an increase in cortical bone mass.[8]

Impaired bone healing: Diabetic status, as characterized by elevated blood glucose and HbA1c levels, can adversely impact bone healing processes.[9]

Vitamin D deficiency: Individuals with diabetes often have decreased serum levels of vitamin D, which plays a crucial role in calcium and phosphate homeostasis, essential for proper bone growth and mineralization.[5,6]

Increased fracture risk: The alterations in bone metabolism and structure induced by diabetes can contribute to an increased risk of fractures, particularly in individuals with longstanding diabetes.[10]

Factors Influencing Mandibular Growth

Apart from diabetes, several factors influence the growth and development of the mandible, shaping its structure and function over time.[11-13] Biological factors, such as genetics, hormonal regulation, and metabolic processes, have a significant impact on mandibular growth. Genetic predispositions can influence the size and shape of the mandible, while hormonal imbalances can disrupt growth patterns.[14] Adequate nutrition is essential for proper mandibular development. Nutrients like calcium, vitamin D, and protein are crucial for bone growth and mineralization in the mandible. Malnutrition or deficiencies in key nutrients can hinder optimal mandibular growth.[15] Functional factors, including masticatory forces and muscle activity, play a role in guiding mandibular growth.[16] The mechanical stress generated during chewing and jaw movement contributes to the remodeling and adaptation of the mandible over time.[15] In addition, environmental influences, such as oral habits (like thumb sucking), breathing patterns, and posture, can impact mandibular growth.[17,18] Abnormal habits or posture can exert asymmetric forces on the mandible, leading to malocclusions and structural deviations.[16,19] Mandibular growth patterns vary at different developmental stages. Growth spurts during childhood and adolescence can significantly impact the length, width, and shape of the mandible.[17]

Proper development of the mandible ensures harmonious facial proportions, which can impact self-esteem, confidence, and overall psychological well-being.[20,21] Proper mandibular development enables efficient mastication, aiding in digestion and nutrient absorption. In addition, along with the maxilla, forms the foundation for speech production. The mandible also plays a role in airway patency and breathing. Proper mandibular growth ensures sufficient space for the tongue, prevents airway obstruction, and supports healthy breathing patterns. The proper alignment and development of the mandible are essential for the health and function of the temporomandibular joint (TMJ).[22] Unbalanced mandibular growth can lead to TMJ disorders, pain, and dysfunction. Additionally, the muscles associated with the mandible play a role in facial expression, chewing, and head posture. Balanced mandibular growth ensures optimal muscle function and alignment, reducing the risk of muscle strain or discomfort.

The Effect of DM in Mandibular Growth

The impact of diabetes on bone growth has been extensively documented in the literature.[4-10] The mandible, as a critical component of the skeletal system, is likely not exempt from the effects of diabetes on bone metabolism and development. Diabetes has a significant impact on mandibular growth, primarily affecting the quality and structure of the mandibular bone. Research indicates that diabetes, particularly Type 1 diabetes can lead to a decrease in bone formation in the mandible. This causes a delay in the growth and development of bones, potentially resulting in a slower rate of skeletal maturation.[19] Studies have shown that in diabetic conditions there is a deterioration in the quality of mandibular bone. This includes a significant decrease in bone volume, bone surface, and alterations in trabecular properties, indicating compromised bone integrity and structure.[19] Abbassy et al.[23] assessed the effect of type 1 DM on the structure of mandibular bone and changes in alveolar/jaw bone formation. Experimental Diabetes induction resulted in a decrease in mineral apposition and bone turnover, significant deterioration of bone quality, and reduced bone turnover around the alveolar wall in rats with diabetes compared to controls.[23] Experimental induction of diabetes in rats resulted in decreased mandibular growth, deformities in mandibular structure, and alterations in various mandibular dimensions. Reductions in growth rates of different mandibular regions were observed following diabetes induction; emphasizing the detrimental effects of diabetes on mandibular growth.[23] Another study highlighted the therapeutic potential of calcitonin and vitamin D3 in improving diabetic mandibular growth. The intermittent combination of calcitonin and vitamin D3 showed promise in enhancing mandibular growth in a diabetic context, suggesting a potential avenue for managing diabetes-related effects on mandibular development.[24] Diabetes can induce biomechanical alterations in the mandible, affecting its strength and overall mechanical properties.[25] These changes can impact the functional aspects of the mandible, including chewing and speech, due to the altered bone composition and quality. The pathophysiological mechanisms underlying the impact of diabetes on mandibular growth involve complex cellular and molecular processes. These include oxidative stress, impaired angiogenesis, altered gene expression, and disturbances in bone remodeling, all contributing to the impaired growth of the mandible.[26]

Understanding how diabetes affects mandibular growth is evidently essential in orthodontic practice. It influences treatment planning, the choice of orthodontic interventions, and the prediction of treatment outcomes in diabetic patients, considering the altered bone dynamics in the mandible. The effects of diabetes on mandibular growth can have long-term implications for dental health and overall well-being. Slowed or impaired mandibular growth may lead to functional problems, malocclusions, and increased susceptibility to dental issues in diabetic individuals. A recent demographic study projects a rising prevalence of diabetes in the coming years.[2] Concurrently, there is an anticipated increase in the number of patients seeking orthodontic treatment. Given this trend, it is imperative for orthodontic practitioners to be cognizant of the potential implications of diabetes on the oral tissues that may be influenced by orthodontic interventions.

Diabetes and Orthodontics

DM both type 1 and type 2, is known to significantly affect various physiological processes, including bone remodeling and healing, which are critical during orthodontic tooth movement. Bone remodeling during tooth movement, treatment timing considerations, alterations in force applications, and healing processes must be taken into account when an orthodontic treatment will be undertaken.

In diabetic patients, the response to orthodontic forces may be altered due to impaired osteoblast and osteoclast activity. Studies have shown that hyperglycemia can lead to changes in bone turnover, resulting in reduced osteogenesis and an increased risk of osteopenia. For instance, a study by Uehara et al.[27] demonstrated that diabetes affects the differentiation and function of osteoblasts, which are vital for bone formation during orthodontic tooth movement. Additionally, An et al.[28] found that diabetic rats exhibited a delayed response to mechanical forces applied to teeth, suggesting that the rate of orthodontic tooth movement may be compromised. Due to potential complications related to delayed healing and altered bone remodeling, practitioners may need to adjust the timing of orthodontic interventions. For instance, Bailey et al.[29] emphasized that optimal glycemic control should be achieved before initiating orthodontic treatment to minimize risks and complications. They found that uncontrolled diabetes not only delayed tooth movement but also increased the likelihood of periodontal complications. Regarding force application a study by Pang et al.[30] indicated that reduced bone density and impaired bone remodeling in diabetic individuals could necessitate the use of lighter forces to achieve tooth movement without the risk of root resorption or periodontal damage. The slower rate of tissue repair and remodeling in diabetic patients can lead to prolonged treatment durations and increased risk of complications. Takahashi et al.[31] reported that diabetic individuals often experience delayed healing due to impaired cytokine and growth factor expression, which affects periodontal tissue response. Consequently, this delayed healing may necessitate longer intervals between adjustments and a more conservative approach to force application.

Mechanisms Underlying the Effects of Diabetes on the Mandible

The mechanisms underlying the effects of diabetes on the mandible encompass a complex interplay of biological processes that impact the growth, structure, and function of the mandible. Diabetes is associated with increased oxidative stress in various tissues, including the mandible. Elevated levels of reactive oxygen species lead to oxidative damage, affecting mandibular bone cells and tissues. Oxidative stress contributes to bone loss, compromises bone regeneration, and impairs the healing capacity of the mandible.[32,33] Chronic inflammation is a hallmark of diabetes and plays a significant role in the pathogenesis of diabetic complications, including those affecting the mandible. Inflammatory mediators released in response to diabetes can contribute to bone resorption, inhibit bone formation, and disrupt the normal bone remodeling process in the mandible.[33] The formation of Advanced Glycation End-Products (AGEs), a consequence of hyperglycemia in diabetes, can impact the structure and function of mandibular bone. AGEs accumulate in bone collagen and impair its mechanical properties, potentially leading to decreased bone strength and increased susceptibility to fractures in the mandible.[34] Diabetes-related vascular complications, including microvascular damage, can affect blood supply to the mandible. Poor vascular health in diabetic individuals can compromise the delivery of nutrients and oxygen to mandibular tissues, leading to impaired bone growth and regeneration.[35] Diabetes-induced neuropathy can also influence the innervation of the mandible, affecting sensory perception, muscle function, and bone remodeling processes. Neuropathic changes in the mandible may contribute to alterations in chewing function, TMJ disorders, and overall craniofacial development.[36] Understanding these underlying mechanisms is crucial for comprehensively addressing the effects of diabetes on the mandible. By elucidating these pathways, researchers and healthcare professionals can develop targeted interventions to mitigate the negative impact of diabetes on mandibular health and function. The relationship between mandibular growth and diabetes presents critical implications for clinical practice and treatment strategies. For this reason research should be directed to uncover the cause and effect relation between diabetes and mandibular growth.

Future Research Directions for Diabetes and Mandibular Growth

Further investigation into the effect of diabetes on mandibular growth is essential to deepen our understanding of this complex relationship and improve patient care. Longitudinal studies examining the long-term impact of diabetes on mandibular growth are mandatory. Investigating how diabetes influences mandibular development over extended periods can provide insights into progressive changes, potential complications, and the stability of treatment outcomes. Exploring the genetic predisposition to diabetes-related effects on mandibular growth is important. Genetic studies could help identify specific markers or pathways that contribute to variations in mandibular development in diabetic individuals, potentially offering personalized treatment approaches.[23] Research focusing on the biomechanical properties of mandibular bone in diabetes is also needed. Understanding how diabetes alters the mechanical behavior, strength, and resilience of mandibular bone can enhance treatment planning in orthodontics and maxillofacial surgery. Investigating the broader impact of diabetes on craniofacial growth, beyond just the mandible, is valuable. Assessing how diabetes influences overall craniofacial development, including facial bone structure and dental arch morphology, can provide a comprehensive picture of the systemic effects of diabetes on oral health.[37] Advanced studies on the cellular and molecular mechanisms linking diabetes to mandibular growth alterations are necessary. Delving deeper into the specific cellular pathways, gene expressions, and signaling cascades involved in diabetes-induced changes in mandibular bone can unveil therapeutic targets and intervention strategies.[32] Clinical trials evaluating the efficacy of therapeutic interventions on mandibular growth in diabetic patients are warranted. Investigating the outcomes of innovative treatments, such as growth factors, bone grafting techniques, or pharmacological agents, can provide evidence-based recommendations for managing diabetes-related mandibular growth issues. Large-scale epidemiological studies focusing on diverse populations are also important, thus more have to be conducted. Understanding how different ethnicities, age groups, and socioeconomic backgrounds respond to the impact of diabetes on mandibular growth can lead to tailored approaches that account for variations in risk factors and treatment outcomes. Artificial intelligence (AI) is definitely a tool that can help uncover previously unknown factors contributing to diabetes while, it can predict in a subclinical level the possibility of an individual to express diabetes. On the other hand, a customized, personalized treatment could be designed for higher treatment efficiency something that AI can play a significant role.[38-40] The existing body of research regarding the effect of diabetes on bone and particularly mandibular bone derives from animal studies. However, it is essential to acknowledge the translational gap that exists between findings derived from animal research and their application on humans and more specifically in clinical orthodontic practice. Additionally, human dental and skeletal development is influenced by complex genetic, environmental, and behavioral factors that may not be fully replicated in animal models.

CONCLUSION

Reduced bone formation, low quality of bone, biomechanical alterations in the bone are the main effects of diabetes on bone growth. This is particularly evident in the mandible, where diabetes can hinder mandibular growth and development, creating challenges for both oral health and overall quality of life mandible as a craniofacial bone is equally affected by diabetes altering the quality and structure of the basal mandibular bone, changing the trabecular bone, while a reduction of bone volume and growth rate is also observed. The mechanical properties of the mandible are also affected decreasing its mandible's strength. The detrimental effects of diabetes on mandibular bone have an impact on several aspects of the mandible itself and the surrounding tissues. As a result, the implementation of effective clinical strategies is crucial for managing bone health in diabetic patients. By understanding the complex interplay between diabetes and bone physiology, healthcare professionals can better address the specific needs of these patients and promote optimal bone healing and strength. Diabetes has a direct impact in orthodontic treatment mainly on bone healing and formation. Special considerations should be taken to adjust the orthodontic treatment in diabetic patients. Future research should be directed towards early subclinical detection of diabetes, while the genetic predisposition is another big chapter that has to be investigated. AI is a tool that has to be used to overcome problems like the inability of early diagnosis, while it will help in creating personalized treatments based on the individual patient special characteristics combined with the characteristics of diabetes, which are expressed in the specific patient.

Footnotes

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