MAXILLARY AND MANDIBULAR BONE STRUCTURES IN RELATION TO DENTAL OCCLUSION: ANATOMICAL AND FUNCTIONAL PERSPECTIVES, A NARRATIVE REVIEW

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Abstract

The maxillary and mandibular bones represent the principal skeletal components of the stomatognathic system and play a critical role in the establishment and maintenance of dental occlusion. Their morphology, growth patterns, and structural adaptation are closely related to functional stimuli generated during mastication and occlusal loading. The alveolar bone surrounding the teeth exhibits continuous remodeling in response to mechanical forces transmitted through the dentition, highlighting the dynamic interaction between skeletal structures and occlusal function. Advances in imaging techniques, particularly cone-beam computed tomography and cephalometric analysis, have significantly improved understanding of dentoalveolar morphology and craniofacial skeletal relationships. These methods allow detailed evaluation of alveolar bone dimensions, tooth position, and maxillary-mandibular relationships that influence occlusal stability. In addition, functional factors such as occlusal force and masticatory activity contribute to structural adaptation of the jawbones, influencing both bone architecture and dental alignment. Understanding the anatomical and functional relationship between maxillary and mandibular bone structures and dental occlusion is essential for accurate diagnosis and effective treatment planning in orthodontics and restorative dentistry.

Keywords: maxillary bone, mandibular bone, dental occlusion, craniofacial anatomy, alveolar bone, stomatognathic system

1. Introduction: Anatomical Basis of Maxillary and Mandibular Bone Structures

The maxillary and mandibular bones represent the principal skeletal components of the stomatognathic system and play a fundamental role in the development and maintenance of dental occlusion. These bones provide structural support for the dentition through the alveolar processes and form the anatomical framework that enables mastication, speech, and other essential oral functions. Dental occlusion is determined not only by the spatial relationship between the teeth but also by the morphology, growth patterns, and adaptive capacity of the maxilla and mandible. Consequently, understanding the anatomical characteristics of these bones and their functional relationship with occlusion is essential for interpreting craniofacial development and for planning orthodontic or restorative treatments [1]. In Figure 1, the frontal view of the human skull and a detailed representation of the mandible. The cranial view highlights the frontal bone, sphenoid bone, and maxilla as components of the craniofacial skeleton. The right panel illustrates the main anatomical structures of the mandible, including the condylar process, coronoid process, mandibular foramen, alveolar process, mental foramen, and mandibular body, which are involved in mandibular movement and mastication.

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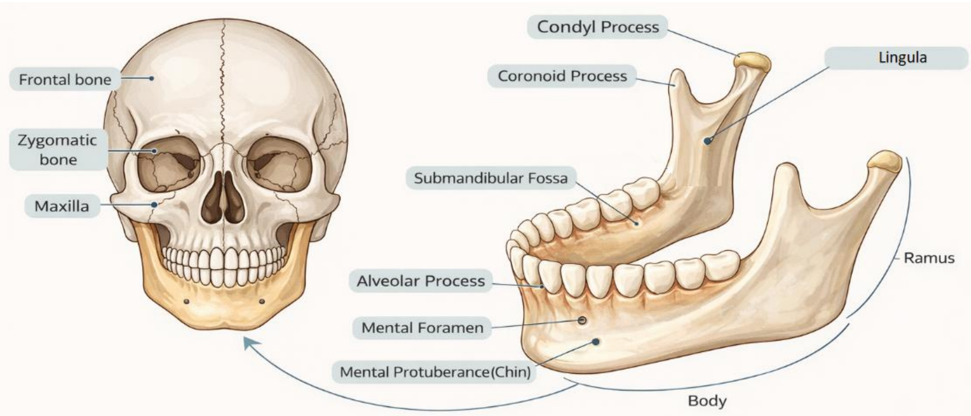

Figure 1. Craniofacial bones and the detailed anatomy of the mandible.

The structural organization of the maxillary and mandibular bones reflects their adaptation to functional demands imposed by mastication and occlusal loading. The alveolar bone surrounding the teeth is a dynamic tissue capable of continuous remodeling in response to mechanical stimuli. Functional loading transmitted through the teeth during mastication stimulates bone remodeling processes that maintain the structural integrity of the alveolar processes. Variations in occlusal forces and masticatory activity may therefore influence the morphology and density of the alveolar bone, highlighting the close relationship between functional activity and skeletal architecture within the oral cavity [2]. Overview of the principal anatomical structures of the maxilla and mandible that contribute to the establishment and maintenance of dental occlusion. The interaction among skeletal components, alveolar bone, and mandibular mobility determines the distribution of occlusal forces and supports the functional stability of the stomatognathic system (Table 1).

Table 1. Main Anatomical Components of the Maxillary and Mandibular Bones and Their Role in Dental Occlusion

Anatomical structure	Structural characteristics	Role in dental occlusion
Maxilla	Paired craniofacial bones form the upper jaw and support the maxillary dentition through the alveolar process.	Provides structural support for upper teeth and participates in the formation of the maxillary dental arch and occlusal relationships
Mandible	A single movable craniofacial bone forming the lower jaw and containing the mandibular alveolar process.	Responsible for mandibular movements during mastication and for maintaining functional occlusal contacts
Alveolar bone	Specialized bone tissue surrounding the roots of teeth continuously remodels under functional stimuli.	Transmits occlusal forces from teeth to the basal bone and adapts structurally to mechanical loading.

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Basal jawbone	Structural foundation of the maxilla and mandible supporting the dentoalveolar complex	Maintains spatial relationships between dental arches and contributes to occlusal stability
TDM interaction	Articulation between the mandibular condyle and the temporal bone allows mandibular movement.	Coordinates mandibular motion necessary for proper occlusal contact during mastication

Experimental studies have demonstrated that mechanical stimulation generated during mastication plays an important role in maintaining bone homeostasis within the jaws. Osteocytes, which act as mechanosensitive cells within bone tissue, respond to mechanical stress by initiating signaling pathways that regulate bone formation and resorption. Increased masticatory activity can therefore stimulate osteoblastic activity and promote the development of stronger and more resilient jawbones. This biological mechanism explains how functional forces contribute to the structural adaptation of maxillary and mandibular bone tissues during growth and adulthood [3].

In addition to cellular responses, functional stimuli may also influence craniofacial growth patterns. Research using experimental models has shown that mastication can affect mandibular growth and alter the internal structure of the jawbone. These changes are related to the adaptive response of the skeletal system to biomechanical loading and are particularly evident during developmental stages when bone tissue exhibits greater plasticity. Such findings emphasize the importance of functional factors in shaping the morphology of the mandibular skeleton and in establishing stable occlusal relationships [4].

Imaging-based investigations have further supported the concept that masticatory function influences the internal architecture of the mandible. Computed tomography studies have demonstrated that variations in masticatory efficiency are associated with differences in trabecular bone structure and cortical thickness within the mandible. Individuals with stronger masticatory function tend to present denser and more structurally organized mandibular bone, suggesting that occlusal loading contributes significantly to skeletal adaptation and structural reinforcement of the jawbones [5].

Occlusal stimuli also play a critical role in the regulation of alveolar and jawbone formation. Mechanical forces transmitted through occlusal contacts may stimulate bone deposition and remodeling processes within the alveolar structures. These adaptive mechanisms ensure that the alveolar bone remains capable of supporting the dentition under functional conditions. Disruption of normal occlusal stimuli, whether through altered occlusion or reduced masticatory activity, may therefore lead to structural modifications of the alveolar bone and potentially affect the stability of dental relationships [6].

The magnitude of occlusal forces generated during mastication represents another important factor influencing the morphology of the alveolar bone. Studies evaluating maximum bite force have demonstrated that individuals with higher occlusal forces often exhibit more robust alveolar bone structures. This relationship suggests that the skeletal components of the jaws adapt to functional demands by modifying bone architecture to withstand the mechanical stress generated during mastication [7].

Advances in three-dimensional imaging techniques, particularly cone beam

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computed tomography (CBCT), have provided valuable insights into the morphological characteristics of alveolar bone in relation to dental occlusion. These imaging modalities allow precise evaluation of bone dimensions, cortical thickness, and spatial relationships between teeth and supporting structures. Such analyses have demonstrated that alveolar bone morphology varies significantly with tooth position, periodontal status, and occlusal conditions [8].

Further CBCT-based investigations have shown that variations in tooth position, such as ectopic eruption or palatal displacement of maxillary incisors, may influence alveolar bone morphology. These findings underscore the close anatomical and functional relationship between dental alignment and alveolar bone architecture, which is essential for maintaining stable occlusal relationships [9].

Orthodontic tooth movement also illustrates the dynamic interaction between dental structures and alveolar bone. Studies evaluating the effects of anterior tooth retraction have demonstrated that controlled orthodontic forces can induce measurable changes in the morphology of the maxillary alveolar bone. Such adaptations reflect the capacity of bone tissue to remodel in response to mechanical forces applied through orthodontic treatment [10].

Morphological differences in alveolar bone have also been identified in individuals presenting specific skeletal patterns, such as skeletal Class II malocclusion associated with an open bite. Three-dimensional imaging studies indicate that these patients may exhibit distinct alveolar bone characteristics, which can influence both occlusal relationships and orthodontic treatment planning [11].

Functional evaluation of occlusion, including measurement of occlusal force, is an important diagnostic component in assessing the relationship between skeletal structures and dental function. Pressure-sensitive films and other diagnostic tools are commonly used to analyze occlusal force distribution and to identify functional deficiencies that may affect oral performance and skeletal adaptation [12].

Age-related changes also influence occlusal function and skeletal adaptation. Studies of adults with natural dentition have shown that occlusal force varies with age, reflecting physiological changes in the masticatory system and potential modifications in bone support structures over time [13].

Radiographic evaluation plays a crucial role in the assessment of craniofacial skeletal relationships and dental occlusion. Cephalometric analysis remains one of the most widely used diagnostic methods for evaluating the spatial relationship between the maxilla, mandible, and dentition. Accurate patient positioning during imaging is essential for ensuring reliable cephalometric measurements and for obtaining precise diagnostic information regarding craniofacial morphology [14].

Finally, the broader concept of craniofacial morphogenesis provides a theoretical framework for understanding the development of the maxillary and mandibular skeleton. Both genetic determinants and functional environmental factors influence the growth and structural organization of these bones. Research on craniofacial morphogenesis emphasizes that skeletal structures adapt continuously to functional demands, including occlusal loading and masticatory activity, throughout growth and development [15].

2. Functional Adaptation of Maxillary and Mandibular Bones to Occlusal Forces

The functional adaptation of maxillary and mandibular bones to occlusal forces represents a fundamental concept in craniofacial biology and dental occlusion. The skeletal structures of the jaws are not static but instead exhibit a dynamic capacity for growth, remodeling, and structural adaptation in response to functional stimuli.

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This adaptive capability allows the craniofacial skeleton to accommodate mechanical loads generated during mastication and to maintain structural stability of the dentoalveolar complex. Theoretical and experimental studies on craniofacial morphogenesis have emphasized that the development of the maxillofacial skeleton is influenced not only by genetic determinants but also by environmental and functional factors, particularly those related to occlusal loading and masticatory activity [15].

Occlusal forces generated during mastication represent one of the primary mechanical stimuli influencing the morphology and internal architecture of the jawbones. These forces are transmitted through the teeth to the surrounding alveolar bone and basal skeletal structures, stimulating cellular responses that regulate bone remodeling processes. The continuous interaction between mechanical stress and bone tissue helps maintain bone density and structural integrity, ensuring the jaws remain capable of supporting the functional demands of the stomatognathic system. Consequently, variations in occlusal force magnitude may influence both the morphology of the alveolar bone and the stability of dental occlusion [16].

Radiographic imaging techniques play an essential role in evaluating the structural characteristics of teeth and surrounding bone tissues in relation to occlusal function. Panoramic radiography, for example, has been widely used to assess root morphology and the relationship between tooth length and supporting bone structures. Accurate radiographic measurements allow clinicians to estimate dental root dimensions and evaluate the structural capacity of the dentoalveolar complex to withstand functional forces generated during mastication. These measurements provide valuable information for understanding the relationship between dental anatomy and occlusal stability [16].

In addition to root morphology, the proportional relationship between the crown and root of teeth represents an important anatomical parameter influencing the biomechanical behavior of the dentition under occlusal load. Root–crown ratios determine the extent of tooth anchorage within the alveolar bone and therefore influence the distribution of occlusal forces transmitted to the surrounding skeletal structures. Studies assessing root–crown ratios in healthy populations have shown that variations in these anatomical proportions may affect tooth mechanical resistance and overall dental occlusal stability [17].

Modern imaging technologies have further improved the evaluation of dentoalveolar structures and their adaptation to occlusal forces. Cone-beam computed tomography (CBCT) enables detailed three-dimensional visualization of root length, alveolar bone morphology, and marginal bone levels. This imaging modality provides clinicians with accurate information about the structural relationships between teeth and supporting bone, which is particularly important during orthodontic treatment, when controlled mechanical forces are applied to induce tooth movement. Continuous monitoring of root length and marginal bone levels during orthodontic therapy helps prevent undesirable structural alterations within the dentoalveolar complex [18].

Beyond local dentoalveolar structures, occlusal function may also influence broader craniofacial relationships, including vertical facial dimensions and airway morphology. Cephalometric investigations have shown that certain malocclusion patterns, such as anterior open bite, may be associated with changes in dentoalveolar height and craniofacial morphology. These alterations may affect both the functional efficiency of the masticatory system and the stability of occlusal relationships, demonstrating the

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close interaction between skeletal structure and occlusal function [19].

Variations in skeletal relationships between the maxilla and mandible may further influence occlusal characteristics and dental alignment. Studies evaluating adults with skeletal Class II and Class III malocclusions have demonstrated that differences in molar heights and incisor inclinations are often associated with distinct craniofacial growth patterns. These structural variations may affect the distribution of occlusal forces and contribute to the development of specific occlusal relationships within the dentition [20].

Taken together, these findings highlight the complex interaction between occlusal forces and skeletal adaptation within the maxillofacial region. The maxillary and mandibular bones respond continuously to functional demands by modifying their internal architecture and structural organization. This dynamic relationship between form and function plays a critical role in maintaining occlusal stability and ensuring the long-term functional integrity of the stomatognathic system [15–20].

3. Morphological Characteristics of Alveolar Bone in Relation to Occlusion

The morphology of the alveolar bone represents a key determinant in the establishment and maintenance of dental occlusion. The alveolar processes of the maxilla and mandible support the dentition and provide the structural framework necessary for the transmission of occlusal forces during mastication. Because the alveolar bone is closely associated with tooth position and functional loading, its morphology is strongly influenced by occlusal conditions, craniofacial growth patterns, and dental alignment. Understanding the relationship between alveolar bone structure and occlusion is therefore essential for evaluating both physiological occlusion and pathological alterations associated with malocclusion [2,5].

Advances in three-dimensional imaging techniques, particularly cone beam computed tomography (CBCT), have significantly improved the assessment of alveolar bone morphology. CBCT allows precise evaluation of bone thickness, height, and spatial relationships between teeth and surrounding structures. Studies analyzing alveolar bone morphology in the anterior maxillary region have demonstrated that bone dimensions may vary with periodontal status, dental alignment, and occlusal relationships. These findings highlight the importance of considering alveolar bone characteristics during orthodontic treatment planning and restorative procedures [8].

Summary of the main morphological characteristics of alveolar bone and their relationship with dental occlusion. Variations in bone thickness, height, and trabecular architecture influence the biomechanical behavior of the dentoalveolar complex and may affect orthodontic treatment planning and long-term occlusal stability (Table 2).

Table 2. Morphological Characteristics of Alveolar Bone and Their Relationship with Dental Occlusion

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Morphological parameter	Description	Clinical relevance of occlusion	References
Alveolar bone thickness	Thickness of buccal and palatal/lingual cortical plates surrounding tooth roots	Influences orthodontic tooth movement, limits, and stability of dental alignment	[8,9]
Alveolar bone height	Vertical dimension of the alveolar bone supporting the dentition	Important for occlusal stability and periodontal support of teeth	[8]
Trabecular bone architecture	Internal structure and density of cancellous bone within the jaws	Adapts to functional loading and masticatory forces	[3,5]
Dentoalveolar adaptation during orthodontic movement	Structural remodeling of cortical and trabecular bone during controlled tooth movement	Allows repositioning of teeth while maintaining skeletal support	[10]
Alveolar morphology in skeletal malocclusion	Variations in bone thickness and dentoalveolar dimensions associated with skeletal discrepancies	May influence orthodontic treatment planning and occlusal relationships	[11]

Variations in tooth position can also influence the morphology of the surrounding alveolar bone. CBCT-based studies of patients with palatally displaced maxillary lateral incisors have shown that abnormal dental positioning may be associated with changes in alveolar bone thickness and morphology. Such structural modifications emphasize the close anatomical relationship between tooth eruption patterns and the architecture of the supporting bone structures. Consequently, disturbances in dental eruption or alignment may contribute to alterations in occlusal relationships through their impact on the dentoalveolar complex [9].

Orthodontic tooth movement further illustrates the dynamic interaction between dental structures and alveolar bone. Controlled orthodontic forces applied to retract anterior teeth can induce measurable changes in the morphology of the maxillary alveolar bone. Three-dimensional analyses have shown that tooth movement may lead to remodeling of both cortical and trabecular bone structures as the dentition adapts to new positions within the dental arch. These adaptive responses demonstrate the alveolar bone's capacity to remodel in response to biomechanical forces while maintaining structural support for the dentition [10].

The relationship between skeletal malocclusion and alveolar bone morphology has also been extensively investigated. In patients presenting skeletal Class II malocclusion with anterior open bite, three-dimensional imaging studies have revealed distinct morphological characteristics of the alveolar bone. These structural variations may include differences in bone thickness and vertical dimensions of the dentoalveolar region. Such morphological features may

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contribute to the development of specific occlusal patterns and influence the biomechanical behavior of the dentition during functional loading [11].

Occlusal function itself represents an important factor influencing alveolar bone structure. Functional loading generated during mastication stimulates bone remodeling processes within the dentoalveolar complex. Experimental and clinical studies have demonstrated that mechanical stimulation from occlusal forces may promote bone formation and maintain the structural integrity of the alveolar processes. Conversely, reduced occlusal loading may lead to decreased bone density and structural alterations within the jawbones [3,6].

The magnitude of occlusal force may also affect alveolar bone morphology. Studies investigating maximum bite force have shown that individuals with stronger masticatory forces often exhibit thicker, more robust alveolar bone. This relationship reflects the adaptive capacity of bone tissue to respond to mechanical stress, reinforcing the concept that alveolar bone morphology is closely linked to functional demands imposed by occlusion [7].

Overall, the morphology of alveolar bone represents a dynamic anatomical component of the stomatognathic system that adapts continuously to mechanical loading and dental alignment. Variations in occlusion, tooth position, and skeletal relationships can influence the structural characteristics of the alveolar bone, emphasizing the importance of integrating morphological assessment into orthodontic diagnosis and treatment planning [8–11].

4. Clinical and Diagnostic Implications of Maxillary–Mandibular Relationships in Dental Occlusion

The structural relationship between the maxilla and mandible plays a crucial role in the diagnosis and management of dental occlusion and craniofacial anomalies. Variations in skeletal morphology, dentoalveolar structure, and occlusal force distribution can significantly influence both the development of occlusion and the functional performance of the stomatognathic system. Consequently, accurate clinical and radiographic evaluation of maxillary and mandibular bone structures is essential for establishing appropriate therapeutic strategies in orthodontics, prosthodontics, and other dental disciplines [1,5].

Clinical assessment of occlusion commonly includes evaluation of dental alignment, interarch relationships, and the distribution of occlusal forces. Occlusal function reflects the interaction between teeth, masticatory muscles, and supporting skeletal structures. Diagnostic tools such as pressure-sensitive films have been developed to quantify occlusal force and to identify functional deficiencies associated with oral hypofunction. These methods allow clinicians to evaluate the efficiency of occlusal contacts and the biomechanical performance of the dentoalveolar complex, which is particularly relevant in patients presenting reduced occlusal force or compromised masticatory function [12].

Age-related changes also influence occlusal performance and skeletal adaptation. Studies investigating adults with natural dentition have demonstrated that occlusal force tends to vary with age, reflecting physiological modifications in the masticatory system and potential alterations in the supporting bone structures. Reduced occlusal force in older individuals may be associated with structural changes in the dentoalveolar complex and may influence the stability of dental occlusion over time [13].

Radiographic imaging remains an essential component in the evaluation of maxillary–mandibular relationships and dentoalveolar morphology. Cephalometric analysis provides valuable information regarding skeletal relationships between the maxilla and mandible, allowing clinicians to evaluate sagittal and vertical craniofacial

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dimensions. Accurate patient positioning during cephalometric imaging is critical for obtaining reliable measurements and ensuring diagnostic precision when analyzing craniofacial structures and occlusal relationships [14].

In addition to cephalometry, panoramic radiography and cone beam computed tomography provide detailed visualization of dental and alveolar structures. These imaging modalities allow clinicians to evaluate root morphology, root–crown ratios, and the relationship between teeth and supporting bone tissues. Such anatomical parameters are essential for understanding the biomechanical behavior of teeth under occlusal load and for predicting the response of the dentoalveolar complex to orthodontic or restorative treatment [16–18].

Cephalometric studies have also explored the relationship between occlusion and other craniofacial structures, including the upper airway and vertical dentoalveolar dimensions. In patients presenting with an anterior open bite, alterations in dentoalveolar height and craniofacial morphology have been reported, suggesting that occlusal patterns may be closely related to skeletal growth characteristics and airway anatomy [19, 23,24].

Furthermore, variations in skeletal relationships between the maxilla and mandible are frequently associated with different types of malocclusion. Studies evaluating individuals with skeletal Class II and Class III malocclusions have demonstrated differences in molar height and incisor inclination, reflecting underlying craniofacial growth patterns that influence dental alignment and occlusal relationships [20, 25].

Overall, the clinical and diagnostic evaluation of maxillary and mandibular bone structures is essential for understanding the mechanisms underlying dental occlusion and malocclusion. By integrating clinical examination with radiographic and functional assessment methods, clinicians can obtain a comprehensive understanding of the structural and functional relationships that govern occlusal stability and craniofacial harmony [1,12,14].

Conclusions

The maxillary and mandibular bones form the structural foundation of the stomatognathic system and play a fundamental role in establishing and maintaining dental occlusion. Their morphology, growth patterns, and adaptive capacity are closely related to functional demands generated during mastication and occlusal loading. The interaction between skeletal structures, dentoalveolar components, and occlusal forces contributes to the dynamic balance required for stable occlusion and efficient oral function. Understanding these anatomical and functional relationships is essential for interpreting craniofacial development and for improving diagnostic and therapeutic strategies in clinical dentistry. Contemporary research highlights the importance of integrating anatomical, functional, and radiographic evaluation when analyzing the relationship between maxillary–mandibular structures and dental occlusion. Advances in imaging technologies, including cephalometric analysis and cone beam computed tomography, have significantly enhanced the ability to investigate dentoalveolar morphology and craniofacial skeletal relationships. These diagnostic tools provide valuable insights into the structural adaptations of alveolar bone and the influence of occlusal forces on jaw development. A comprehensive understanding of these mechanisms is crucial for accurate orthodontic diagnosis, treatment planning, and long-term maintenance of occlusal stability within the craniofacial complex.

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