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The Association between Mastication, Malocclusion, and Craniofacial Morphology

Research Article

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Abstract

Mastication is the first step of food intake and digestion, which is a complex act that requires the participation of the whole functional stomatognathic system. Among all its components, teeth are regarded as the executor and take the main charge of mechanical food breakdown. Based on this, many researchers suspected that there is a mutual effect between malocclusion and masticatory function, and made efforts to figure out their interrelationships. Various studies have revealed that the alteration of occlusal patterns may decrease masticatory capability, and orthodontic treatment is an efficient solution. On the other hand, it is also detected by clinicians that masticatory anomalies can have a long-term impact on the formation of malocclusion and dentomaxillar deformities. But due to the complexity of stomatognathic system and the uncertainty of individual growth, this theory has not yet been sufficiently validated. Therefore, in order to define dental positions tuned to masticatory capabilities, it is necessary to understand how different associated factors including the properties of food textures, masticatory muscles, bite forces and chewing patterns affect dental positions and craniofacial growth in the long run. This review is determined to summarize the previous evidence and try to illustrate a potential rule so as to avoid postponed intervention and correction of subsequent masticatory dysfunction and malocclusion.

Abbreviations: ACNC: Areas of Contact and Near Contact; BSE: Backscatter Electron; DMD: Duchenne Muscular Dystrophy; FSHD: Facioscapulohumeral Muscular Dystrophy; UPCB: Unilateral Posterior Crossbite.

Introduction

These days, the prevalence of malocclusion and craniofacial deformities seems significantly increased compared to industrial age [1]. Physical anthropologists attributed these changes in dental occlusion greatly to the transition of modern diet [2], and suggested mastication or chewing habits might have a long-term effect on dentofacial growth and development. This topic has attracted interests from both orthodontists and physiologists, and abundant studies were conducted to explore the association between mastication, malocclusion and craniofacial morphology.

Mastication or chewing is defined as a process of mechanically breaking down food into smaller pieces so that it can be further digested by enzymes. The coordination of masticatory function is based on the harmony in stomatognathic system, including teeth, periodontal tissues, craniofacial bones, masticatory muscles, temporomandibular joint and nerve system. Otherwise, masticatory dysfunctions may occur, which render lower masticatory performance. It has been found that various factors could play a role in the function of mastication [3]. Since teeth are the final executor shredding and comminuting food, it may be hypothesized that malocclusion could also decrease masticatory function and performance.

As for malocclusion, it is a developmental deformity characterized by incorrect relationships between the teeth and two dental arches. The etiology of malocclusion or dentofacial deformities has not-yet been fully understood. Generally, it is regarded as the result of a complex interaction among multiple factors like genes, environment, bad oral habits and oral functional disorders [4-7]. According to functional matrix theory [8], persistent disequilibrium of stomatognathic system could result in malocclusion and craniofacial deformities, which has been verified in patients presenting mouth breathing habits [7] and swallowing disorders [6]. Masticatory function is also one of the most essential abilities

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conducted by orofacial system, and its abnormality seems to affect tooth eruption and render skeletal morphological changes in children and adolescents as well [9, 10]. To date, many clinicians have witnessed that greater use of the jaw or more prolonged biting force could increase the dimension of dental arches [11]. But whether it is because of the strengthened masticatory muscles [12] or the increased stimulation of force transduction into craniofacial bones [13] has not been fully clarified. Moreover, chewing is a dynamic act, which varies in rate, duration and spatial aspects (e.g., kinetic trajectory and lateral excursion) [14]. Those factors might also influence the growth and development of craniofacial areas in the long run.

Overall, although the association between mastication, malocclusion and craniofacial morphology has long been investigated, we are still inadequate to draw a firm conclusion. This review is determined to summarize the previous evidence in order to enhance our knowledge in this field. Due to the complexity of masticatory process and the uncertainty of individual growth, the long-term effect of mastication on dentomaxillary complex will be further illustrated according to influential factors, i.e. food textures, masticatory muscles, bite force and chewing patterns.

Malocclusion and Masticatory Function

Masticatory performance is a direct quantitative evaluation of masticatory function. It scales one's ability of breaking down food according to particle sizes after a specific chewing cycle numbers [15]. Many factors like age, gender, BMI, bite force and occlusal contact areas have been proved to have an impact on masticatory performance [16, 17]. Malocclusion, to some extent, is regarded as a form of mutilated dentition, which could negatively affect masticatory function based on mechanical disadvantage [18]. Over the past decades, the association between malocclusion and masticatory function have been studied but the results remain controversial.

Several studies compared the masticatory performance of different types of malocclusion based on Angle Classifications. Toro et al., [19] found children who had normal occlusion performed better in mastication than those with Class I malocclusion, but no significant difference was detected between those with neutroclusion and distocclusion. However, after conducting a longitudinal study on a larger sample, Barrera LM et al., [20] found there was no significant difference among the three occlusal types, which seemed to contradict previous results drew by English et al., [18] and Henrikson et al., [21] who detected that children with normal occlusion had better masticatory performance than those with Class II and Class III malocclusions. The inconsistence might result from the difference in study subjects. English et al., collected patients who sought orthodontic treatment, while Toro et al., recruited children from school. Therefore, we may conclude that the severity level of malocclusion is a considerable aspect affecting masticatory function, and the Angle Classifications of malocclusion might not directly correlate with masticatory performance.

Apart from analyzing the association in terms of Angle Classifications, Choi TH et a1., [23] utilized objective and subjective methods to examine the masticatory function of individuals with vertical craniofacial discrepancies, i.e. anterior open-bite and posterior cross-bite, then revealed the masticatory function of patients with those types of malocclusion are significantly reduced.

The concept of "areas of contact and near contact"(ACNC) was proposed as a direct factor influencing masticatory performance among subjects with different malocclusion types. Owens S et al., [17] detected individuals with larger ACNC showed better masticatory performance, while sagittally maloccluded patients who have less ACNC performed worse in mastication. The number of occlusal pairs and occlusal curvature were also reported as two influential factors to masticatory performance. Riosvera V et al., [24] reported the pairs occluding teeth were associated both with malocclusion and masticatory performance but there was no direct correlation between malocclusion and masticatory function. Fueki K et al., [22] found individuals with flatter occlusal curvatures had better masticatory performance and mixing ability. Overall, although the above factors may not be mutual independent, we could still speculated that traditional descriptors of malocclusion types might not interpret the variation in masticatory performance, but some occlusal factors do.

To conclude, severe malocclusion could play a negative role in mastication and it might be due to the impact of diverse occlusal factors. Malocclusion type is not a direct indicator for masticatory dysfunction and we cannot simply ascribe the changes in masticatory function to the classifications of malocclusion.

Long-term effect of Mastication on Malocclusion and Craniofacial Growth

Food Textures, Mastication and Craniofacial Development

Chewing is a semi-automatic act, which is governed by the feedback of periodontal mechanoreceptors and could also be mediated by intentional self-adjustments. Periodontal receptors can react from disparate characteristics of food bolus and then send signals to neural center for motivating an appropriate chewing pattern [25, 26].

Historical views about the effect of disparate food textures are associated with changes in masticatory muscle performance governed by afferent feedbacks [12], therefore influence craniofacial development in the long run. Some anthropologists believed that a decrease in masticatory stress among softer dieters can cause smaller mandibles and craniofacial sizes [2, 11]. This assumption has been validated in animal experiments. Ciochon RL et al., used minipigs as subjects and detected those in softer diets had greater facial prognathism, arch narrowness and severer crowding compared to hard dieters [27]. Growing rats with masticatory hypofunction created by powder-feeding also exhibited maxillofacial deformities [28]. Another discovered effects of food textures were on the growth of mandibular condyles. Tanaka E et al., [29] found the trabecular bone of condyles in hard-diet rats was less mineralized than that in the control group, which indicated hard-diet rats were experiencing a more active remodeling in the mandibles. Dias GJ et al., [30] drew a same conclusion using piglet models but observed the condyles in hard-diet group had higher mineralization levels based on Backscatter electron (BSE) imaging and histology examination. The difference in the degree of mineralization possibly owes to the different periods of calcification. To sum up, all evidence points to the conclusion that the properties of food textures could have a long-term impact on craniofacial development, which might be conducted via the changes in masticatory muscles and mandibular condyles.

Recently, some researchers propounded that different properties of food textures could play an essential role in the improvement of mandibular control and the coordination of masticatory apparatus [14]. It is believed that children gradually refine their chewing skills, which can be boosted by solid textures [32]. Compared to the beginners, sophisticated chewers are more experienced in adjusting their mandibular movement based on the properties of their food. The acknowledgement about the toughness of chewing task help chewers elicit greater bite force, faster jaw movements and more chewing cycles [33, 34], which would benefit the coordination of masticatory apparatus. On the contrary, reported immature chewing patterns involve abnormal lateral and vertical jaw displacement, increased chewing duration and number of chewing cycles per bite [14]. Would those chewing inefficiencies, if persist, contribute to the changes in masticatory muscles, temporomandibular joint and craniofacial development? The answer is still unclear. By analyzing three groups of people in childhood, adolescent and adulthood, Geoffrey E et al., [35] found that chewing cycle duration appeared to adapt with age, and is more linked to "functional" variables, i.e. jaw length and size, but not associated with "aesthetic" cephalometric parameters like ANB. He also observed no remarkable correlation between chewing rate and jaw length, which is consistent with previous findings in dog [36] and horse [37] models. Therefore, food consistency can affect children's acquisition of chewing skills and might play a potential role in the development of craniofacial morphology, but future studies are still needed.

Muscles of mastication affect jaw growth

The contractile activity of masticatory muscles is the driving force of mastication and jaw movements. The elevator muscles, which include masseter, temporalis and medial pterygoid, contract during occluding and show maximum activity when clenching in intercuspal position. As for disoccluding phases, lateral pterygoid and some suprahyoid muscles exhibit prominence and help mandible descend. Technically, suprahyoid muscles do not belong to masticatory muscles, but they are essential to stabilize both jaw and hyoid, and are involved in jaw-opening process.

The masticatory muscular dystrophy can generate malocclusions and craniofacial deformities. Patients with Duchenne muscular dystrophy(DMD) have an increased occurrence of open-bites and cross-bites with their severity aggravates over time [39]. Eckardt L et al., believed that the deterioration of masseter muscles and the enlargement of hypotonic tongue might be the reason of sagittal underdevelopment and transverse overdevelopment of dentomaxillary complex respectively [40]. Another craniofacial deformity could be seen from patients with facioscapulohumeral muscular dystrophy (FSHD), which involves progressive facial muscle atrophy and weakness. Patients with FSHD have narrow arches, high palates and different degrees of malocclusion [41]. Because of the limitation on direct interference with human subjects, many studies use animals for substitute to analyze the long-term effect of altered masticatory muscles on craniofacial formation and development. Sidney L et al., [42] removed one side of masseter muscle in growing rats and detected severe modifications of cranium, mandible and dental arches. Veccione L et al., [43] also found morphological changes in skulls and mandibles in myostatin-deficient mouse models, which suggested hypermuscularity significantly correlated with skeletal growth. All above studies indicate the fact that normal masticatory muscle function is the foundation of sound dentofacial growth and development.

Apart from severe pathologic abnormalities of masticatory muscles, some types of malocclusion are accounted for long-term effects of irregular muscular activities and subsequent forces applied on the skeleton during craniofacial growing period. Some researchers revealed the alteration in muscular activities after functional treatments could contribute to the establishment and maintenance of a new dento-skeletal relationship [44-46]. Additionally, some studies found masticatory muscular abnormities could play a role in the formation of unilateral posterior crossbite(UPCB). Woźniak K et al., [47] observed that the activities of both temporalis and masseter muscle significantly decreased in UPCB patients compared to those without malocclusion, and the imbalance torque of the two pairs of muscle was responsible for the lateral functional shift of the mandible. Raoul G et al., [48] analyzed the phenotype of masseter muscle in patients with asymmetric mandible and found the percentage of type II fibers on the jaw deviation side significantly increased than the contralateral side.

However, current views about the association between separate masticatory muscle activities and the types of malocclusion remain controversial. A lack of large sample analysis might be a reason. Another is that medial and lateral pterygoid muscles are located beneath the surface, therefore it requires invasive methods to detect the activities in those muscles. Moreover, there are various mandibular positions and movements, which increase the difficulty in investigating all conditions. Nishi S.E, et al., [49] found the activities of masseter muscle during masticatory process exhibited linear association with overjet in distocclusal patients. Tecco, et al., [50] found no significant difference in activities of masseter and temporalis among patients with Class I and Class II malocclusion no matter at rest position or during the period of maximum voluntary clenching, but both pairs of muscle in Class III subjects showed higher activities than the other types of malocclusion at mandibular rest position. Similarly, Cha BK [51] detected that Class III patients have a higher resting temporal muscle activity and their masseter muscle activity increased less when clenching compared with other skeletal types. As for vertical malocclusion types, its association with masticatory muscle activity levels is also unclear. Some researchers found the activity duration of masseter muscle was remarkably longer in individuals with hypodivergent discrepancy [52], while some detected no significant difference between individuals with short and long faces [53]. Therefore, it is still insufficient to demonstrate the specific long-term effect of each masticatory muscle on malocclusion, and further studies with larger sample and higher quality are required.

Bite force, malocclusion and craniofacial morphology

Bite force, which is an intermittent load directly implemented on teeth and dental arches while chewing, could be a physiological or pathological factor to dentomaxillary complex [54, 55]. Since real-time bite force during mastication is hard to test, most researchers evaluated maximum bite force as a representative and explored its association with malocclusion and craniofacial morphology.

Unfortunately, up to now, there is no clear evidence for a direct relationship between variation in bite force and the sagittal patterns of malocclusion. Roldán S et al., [56] found children with normal occlusion have stronger maximum bite forces compared with those with malocclusion, but no remarkable difference was detected between subjects in Class I and Class II malocclusion. However, De B.L.L et al., [57] observed that the bite force in individuals with normal occlusion did not differ from those with malocclusion, which is consistent with other study results analyzed according to Angle Classifications [58, 59]. As for vertical patterns of malocclusion, it seems to associate with maximum bite force. Several researchers have announced that subjects with anterior open-bite and posterior cross-bite showed weaker maximum bite forces than those with normal occlusion [23, 60]. Considering non-sagittal malocclusions always appear along with craniofacial discrepancies, some researchers postulated that the relationship between malocclusion and bite force is more likely to scale with other factors (e.g. masticatory muscles) than with malocclusion type [61].

In terms of craniofacial growth, some researchers observed bite force was closely correlated with vertical dimension of craniofacial morphology in adults [62, 63]. Individuals with hyperdivergent discrepancy have lower maximum bite force than the brachyfacial ones. A larger bite force was correlated with a larger posterior-anterior face height proportion, a smaller mandible inclination and a smaller gonial angle [64]. It was previously assumed that lower bite force possibly allowed excessive posterior teeth's eruption during crucial period of craniofacial growth and then contributed to a clockwise rotation of the mandible. However, Proffit WR et al., [65] were unable to find a difference in bite force between 6 to 11-year-olds with long faces and normal faces, which suggests craniofacial discrepancies pre-exist the variation in bite force. Therefore, it is reasonable to speculate that bite force in the long run can affect craniofacial morphology but it might not be an initiator for vertical dentofacial discrepancies.

Chewing patterns and malocclusion

Chewing is a highly complex process with a diversification in rhythmic mandibular movements, which makes adjustment to food properties, occlusal contacts, temporomandibular joints and neuromuscular system. There are various chewing patterns exhibited in individuals with different occlusion types but the classifications involved have not yet been established as an agreement [66-68]. Reverse chewing cycle is one of the irregular chewing patterns studied most due to its close correlation with posterior cross-bite. It is characterized with a lateral excursion before descending the mandible, while normal chewing pattern is identified as mandible moving downward first from centric occlusion and then laterally before returning back to intercuspation [68]. Many clinicians suggested that frequent reverse chewing cycles might be a functional disorder and in the long term contribute to dental malposition or craniofacial asymmetry [69], but there is still a lack of sufficient evidence.

Up to now, it has only been well examined that patients who have posterior cross-bite exhibited a high prevalence of reverse chewing cycles. Proeschel PA et al., [67] observed that patients with cross-bite showed more reverse chewing patterns, while those with Class I and II malocclusion presented normal sequencing chewing cycles. Apart from adults, Sever E et al., [69] collected children in primary dentitions as subjects and also found the number of reverse chewing pattern increased in those with posterior cross-bite when masticating on the affected side. They then hypothesized that reverse chewing patterns might cause abnormal growth and suggested early treatment to eliminate this functional disorder. However, some researchers hold opposite views and argued that the reverse chewing cycle was a typical pattern for children in primary dentition, and there was no indication for early treatment required [70, 71]. Tsanidis N et al., [73] studied the evidence in functional changes of UPCB patients after early orthodontic intervention and found their chewing patterns tended to normalize, which suggested dento-skeletal asymmetry might result in reverse chewing cycles, not the other way around. Irregular chewing patterns may not be an initial factor for dentofacial deformities and there is a lack of long-term observation in the effect of reverse chewing cycles on individual growth.

To sum up, despite a close correlation between reverse chewing cycles and UPCB, there is still a gap in the field whether irregular chewing patterns can render malocclusion and craniofacial deformities or not, which requires further longitudinal prospective studies and high quality evidence.

Conclusion

• Malocclusion can have a negative impact on masticatory performance based on mechanical disadvantage, but the Angle Classification does not directly associate with the variation in masticatory function.
• Food textures can influence craniofacial morphology via masticatory muscles and condyles, and it is associated with the development of mandibular control and masticatory coordination.
• Masticatory muscular abnormities contribute to the occurrence of malocclusion and craniofacial deformities, but it is still insufficient to determine which specific role does masticatory muscle play in terms of craniofacial growth.
• Although bite force is not a cause of malocclusion and craniofacial discrepancies, it may have a long-term effect on the vertical dimension of craniofacial morphology.
• Despite the fact that reverse chewing cycles are closely related to posterior cross-bite, it is still lack of evidence for a high prevalence of irregular chewing patterns initiating malocclusion in the long run.

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Special Issue on

" Long-Term Effects of Orthodontic Treatment"

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