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Review article

CRANIOFACIAL DEVELOPMENT OF THE CHILD

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ABSTRACT

This article briefly describes the mechanisms of cranio-facial growth and the role of the forming functions (namely mastication, breathing, swallowing and speech) in achieving a harmonious development. Facial sutures are joints and important sites of bone growth with visco-elastic characteristics that distribute forces to the whole cranial structure that remain well into adulthood. An equally important role is played by the temporomandibular joint, which undergoes a major change in morphology during growth, constantly accompanying the changing oral functions (from suction to mastication and speech); the mandibular condyle is an important site of bone growth, with a large capacity to adapt or to compensate. The ability of this joint to compensate is a lifelong adaptive process that takes place in interplay with everchanging occlusal conditions. The temporomandibular joint's dramatic involvement in children affected by juvenile idiopathic arthritis is quite obvious, with or without signs or symptoms. Some malocclusions, and the cross-bites in particular, alter both the occlusion and the masticatory function, leading to an altered cranial development that is irreversible at the end of growth.

Recently, laboratory and clinical research have highlighted, in animal models of reduced mastication, an association between the experimental reduction of the masticatory function and a significantly reduced number of hippocampal neurons, neurogenesis in the dentate gyrus, synaptic density, and increased glial activity, as well as reduced memory and spatial orientation.

Mastication is, therefore, central to the craniofacial development of the child and the development of cognitive functions. Therefore, the treatment of malocclusions must be respectful of physiology and biology to re-establish all the functions of the growing stomatognathic apparatus and avoid traumatic treatments whose effects are impossible to anticipate and prevent, given the developing system's complexity and its importance for future functional and cognitive balance.

KEYWORDS: *Mastication, craniofacial growth, cognition, memory, malocclusion*

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INTRODUCTION

Craniofacial growth does not end in a simple volumetric increase: it is a rather complex individual process influenced simultaneously by the genetic / family characteristics of the child and the functions of the stomatognathic system (1–5). The growth of the individual bones of the skull is achieved thanks to apposition and resorption processes, which simultaneously allow for the increase in volume and progressive structural remodeling, including repositioning in the three planes of space. Each bone is repositioned according to its growth and the growth of the surrounding bones and soft tissues (1, 6). The development of the skull is, therefore, the result of the integration of volume increases, regional remodeling, and repositioning, which, interacting with each other, adapt, in physiological conditions or compensate, in pathological conditions, the anatomical structure in response to the changing functional needs (7, 8). The soft tissues surrounding a bone (muscles, ligaments, vessels and nerves, teguments) represent the functional matrix capable of influencing growth through functional stresses, among which chewing plays a particularly important role (9). Therefore, the adaptation or compensation of craniofacial structures must be understood as a response to the genetic and family characteristics of the individual, in turn, influenced by the characteristics of the soft tissues and function (Fig. 1).

Fig. 1. *Median palatine suture at the age of 4: an important growth site in the course of development.*

It is important to remember that adaptation occurs in physiological conditions concerning anatomical conditions that change, for example, with aging. At the same time, compensation is a reaction to pathological structural conditions, which the system cannot self-correct to maintain the best possible function. The compensation, which immediately allows the most effective function, can trigger a chain of harmful pathological reactions, as occurs in cross bites.

Malocclusion is a pathology of the anatomical structure of the craniofacial complex that interacts with a cause/effect relationship with the genetic predisposition on the one hand, and functional conditions, on the other.

The chewing function plays a central role in the growth and development of the child's splanchnocranium, especially in early and second childhood. The forces of chewing and swallowing are necessary for growth, and their alteration significantly disturbs the development of the stomatognathic system; however, even in adulthood and during aging, they are important for health and quality of life. International research results have for some time now unequivocally highlighted the association between some malocclusions and the alterations/pathologies of chewing (10). Furthermore, recent basic and clinical international research results have also shown a link between chewing function and cognitive development (11). In fact, in animal model, the experimental reduction of chewing is significantly associated with alterations of the hippocampus, demonstrable both on a histological and behavioral level, which we will describe shortly.

Chewing, therefore, is not only of dental interest but also concerns the child's and adolescent's development. Traumatic orthodontic therapies during development, although widespread in the world, often act against functional physiological principles and require a biological price that is sometimes very important and worrying, as shown by recent studies in the field (12). The purpose of this article is, in the light of recent research results, to describe some fundamental evolutionary stages related to the functions of the masticatory organ, to facilitate the understanding of the etiopathogenesis of malocclusions as well as the importance of a correct therapeutic approach, in a logical and consistent path with the diagnosis and with the characteristics of craniofacial growth.

The role of facial sutures and the temporomandibular joint during growth

Craniofacial growth, far from being the exclusive result of the expansion of a few growth centers, involves all the bones and joints of the skull (1). However, some structures play a particular role in growth, adaptation and/or compensation and deserve a particular description: the facial sutures and the temporomandibular joint.

The facial sutures have different characteristics and respond to different stimuli than the neurocranial sutures: while the latter is stimulated by the expansion of the brain, which mainly follows a genetically determined program, the facial sutures are stimulated by the forces of the function of the stomatognathic system, i.e., chewing, swallowing, breathing and phonation. The presence of adequate stimuli is essential for developing and maintaining craniofacial sutures. In fact, they do not have intrinsic growth potential, and the deposition of bone on the two sides of the suture is stimulated by tensional, intermittent stresses (13). It is known from the basic research that the reduction of the masticatory function in the growing animal significantly decreases the bone apposition at the level of the sutures of the upper jaw, which become slightly patent and not very active (14,15). The reduction of muscle activity leads to morphological changes in the suture (16). Facial sutures, such as the fronto-maxillary, the naso-maxillary, and the zygomatic-maxillary, remain open for a very long time in physiological conditions until the seventh/eighth decade of life (17). The presence up to late age of the visco-elasticity characteristics of the sutures allows the loads generated by muscle function (chewing, swallowing, and speaking) to be effectively cushioned by the entire cranial structure. The trauma and the consequent premature ossification of the sutures, an inevitable consequence of traumatic and non-physiological therapies applied to the palatine suture and to many other facial and neurocranial sutures, do not allow the full performance of their growth function, nor their biomechanical distribution role of loads over the course of life.

The maxillary bone has an intra-membranous origin, and its growth occurs by sutural apposition and superficial remodeling at the periosteum. The median palatine suture (Fig. 1), an important growth site (18,19), along which the horizontal laminae of the palatine bones articulate posteriorly, and the palatine processes of the maxillary bones anteriorly, plays a primary role in the dimensional increase of the palate. It goes without saying that malocclusions due to insufficient growth of the upper jaw bones must be corrected by stimulating growth in a physiological and certainly not traumatic way, under penalty of an individual biological and functional price in the oral environment, present and future.

The growth of the mandible is different and peculiar: the condyle region develops through the enchondral route, while the rest of the mandible initially follows an external cartilage sketch (Meckel's cartilage, mantle ossification) and develops then by periosteal deposition (1). Unlike other cartilages of the skull, such as the synchondrosis of the skull base, or of the cartilage of the nasal septum, of direct mesenchymal derivation, particular attention must be paid to the condylar, which is a secondary cartilage. The growth of the temporomandibular joint is adaptive (or compensatory, in pathological conditions) and occurs in response to mechanical stimuli (20). The articular fibrocartilage that lines the head of the condyle is initially well represented and nourished by a rich vascularized connective tissue, which allows rapid growth during development. In fact, at birth, the temporomandibular joint is completely immature; over the years, the potential decreases, but continues to maintain a considerable capacity for adaptation or compensation for the entire duration of the individual's life (20,21). The temporomandibular joint actually changes during growth, constantly accompanying the evolution of its function: in the first years of life it has a flattened morphology, an expression of its function as a "flat" sliding joint suitable for sucking movement; subsequently, the joint eminence becomes progressively steeper and the condyle moves away from the occlusal plane (22, 23). Compensation of the temporomandibular joint is a lifelong adaptation process with respect to changing occlusal conditions.

The remarkable adaptability is demonstrated by studies on animal model, in which the application of a device designed to induce an asymmetrical lateral displacement of the mandible determines a different development of the two condyles (10). Similarly, in small patients with deciduous or mixed dentition presenting a crossbite-type malocclusion, which causes dislocation in the three planes of the mandible space, the two condyles are subjected to different stimulations during the course of function and their compensatory growth is asymmetrical, irreversibly at the end of growth (24). This is a predisposing condition to chronic craniofacial pain.

In light of the adaptive growth characteristics of the temporomandibular joint in the development phase, particular attention should be paid to a systemic inflammatory disease such as juvenile idiopathic arthritis (JIA). Due to the characteristics described above, the JIA involves the growing temporomandibular joint in an important and constant manner, even in the absence of obvious or reported signs and symptoms. In fact, it is rare for growing patients affected by JIA to report painful symptoms affecting the temporomandibular joint, although the latter is always affected by the pathological inflammatory process. It has been shown that, in the presence of JIA, the growth of the mandibular condyles proceeds asymmetrically, deviating significantly from the growth pattern of unaffected subjects (25,26). The asymmetry involves the condylar height and has repercussions on the vectoriality of the general cranial structure: in fact, cephalometric studies have highlighted a significant prevalence of hyperdivergence and postero-rotation of the jaw in patients with JIA compared to unaffected subjects. This is a type of cranial structure with a high risk of developing intrinsic asymmetries, occlusal instability and dysfunctions of the oral sphere: it is not surprising, since the condyle is an important site of growth and adaptation/compensation of the functions of the cranial structure (27). In growing patients affected by JIA, therefore, it is necessary to monitor and treat the temporomandibular joint function regardless of the presence of signs and symptoms affecting it. Therefore, the orthognathic treatment must be of the gnathological type, that is, respectful of physiology, avoiding any traumatic mechanics whose side effects could add to the altered dynamic pattern of the skull structure, worsening it further.

Shaping functions

The dental arches are rigid structures that dominate the system and from which continuous proprioceptive signals depart, leading to the formation of patterns and motor memory. The oral functions of each functional period are forming functions; that is, they have a decisive influence on the morphology of the bone structures and the formation of functional motor patterns (28). Since the main motor of bone growth resides precisely in the functional matrices, an altered function or deforming influences such as malocclusions or spoiled habits, can, at any stage of the evolution of the chewing organ, but especially in the earliest ones, disturb the harmonious development of the craniofacial complex. Poor habits, oral breathing, atypical swallowing (with the interposition of the tongue or lower lip), prolonged use of the pacifier and sucking, especially of the thumb, can be responsible for disharmonic development (29). It would be a mistake to allow such dysfunctions and asymmetries to mature.

Starting from birth, many studies highlight the importance of breastfeeding in promoting the correct development of chewing muscles and jaw structures in the three dimensions of space (30). It should be remembered that the physiological sign of change and transition from sucking to swallowing is represented by the eruption of the first deciduous tooth which occurs on average at six months. From this moment on, the system begins its evolution towards adult swallowing and chewing. Prolonged breastfeeding beyond the first year of age represents an obstacle to the physiological evolution of swallowing and chewing function.

In addition to chewing and swallowing, respiration and speech are important functions in the growing subject: their functionality must be carefully monitored to detect anomalies early. Verbal communication, from the early stages of echolalia to fully developed language, involves neuromuscular activations that are less intense than chewing and swallowing but nevertheless important for development: phonation is also a shaping function.

Among the anatomical pathologies capable of significantly altering the chewing function and, therefore, the cranial bone growth irreversibly unbalancing it, there are certainly malocclusions, including open bites and all types of cross-bites. In particular, the rear unilateral cross-bite is the most common. This asymmetrical malocclusion has been defined as a neuromuscular syndrome because it causes pathological changes in the masticatory pattern and neuromuscular coordination, resulting in a severely asymmetrical function (31). International research studies have shown for some time that, in cross-bite conditions, abnormal dyskinetic and poorly efficient patterns develop during cross-biting, neuromuscular coordination between the sides is lost and the electromyographic amplitude reaches values about 50% lower than the unaffected side (32,33). Faced with such an important functional asymmetry, an asymmetrical development of the craniofacial structure will occur, primarily involving the joints, irreversible at the end of growth (34, 35). A peculiarity of this malocclusion is represented by the fact that it can manifest itself in deciduous dentition as early as 2-5 years of age, during the formation and fine-tuning of all neural motor schemes; therefore, its early diagnosis is important and the therapy becomes longer and at risk of relapse the later the intervention is carried out. Orthognathic therapy of the posterior cross-bite is not only aimed at repositioning the teeth within the arches in the correct occlusal relationship, but above all, through the teeth, to rebalance the chewing function between two sides. It goes without saying that it will not be possible to recover function with traumatic and anti-physiological mechanical therapies, but only with therapies that respect the physiology and biology of the system. The earlier this happens, the sooner the residual memory is corrected, the growth will become harmonious and the correction will easily remain stable over time.

Recent research results: chewing function and cognitive development

In recent years, it has emerged from studies on animal models that the experimental alteration of the chewing function causes alterations in the central nervous system, demonstrable from a histological and behavioral point of view (34,35). Animal studies are important for histological and biochemical demonstration; in fact, in the mouse model, the imposition of a soft diet right from weaning, in addition to the marked underdevelopment of the jaws (which is not reflected in the somatic development, which proceeds (36), is associated with the significant reduction in the number of neurons, reduction of neurogenesis in the dentate gyrus, reduction of synaptic density and activation of glial cells in the hippocampus, as well as a reduction in memory and spatial orientation. Furthermore, the chewing function is disturbed by a mechanical obstacle, such as a pre-contact inserted between the arches in the molar or incisal region that prevents any other occlusal contact (called bite-raise, nowadays widely used especially in adolescence), in addition to the neural alterations described in the hippocampus. In that case, there is an activation of the hypothalamus-pituitary-adrenal axis, with an increase of corticosteroids. In fact, in the animal model the bite-raise creates a state of uncontrollable anxiety in the condition of new stressful stimuli, which persists even after the acute response is exhausted (37). In other words, occlusal stability is an important element for a child's harmonious psycho-physical development. Occlusal stability is the condition in which, during the closing movement of the mouth, the dental arches easily find the maximum intercuspation and the antagonist teeth face each other with a dense distribution of contact points, allowing the development of adequate forces to stimulate the bone growth (38). The unstable occlusion, on the contrary, does not allow adequate development of the functional forces necessary for the growth of the jaws and in addition, it has a negative influence on the cognitive development of the child. Achieving stable occlusion with adequate anterior canine guides is the aim of any orthognathic therapy (39-45).

There are therefore at least two distinct functional aspects to take into consideration: on the one hand, the occlusion, which can, if altered, be a source of stress for the body; on the other hand, the chewing function, which can, if exercised too little or altered by malocclusions or other congenital or acquired pathologies, negatively affect the trophism of the hippocampus and its functions. This has been demonstrated both during weaning and growth, and during aging. From clinical research, it is known that the presence of less than twenty teeth in the arch (considered the limit for efficient chewing) is associated with a reduction in cognitive performance in the elderly subject, which is completely consistent with the data from laboratory studies, as well as from clinical experience (46,47, 48). It must be emphasized that alterations in chewing and / or occlusion can lead to a reduction in the neuronal potential which otherwise allows aging to be faced with an adequate functional reserve necessary for maintaining a good quality of life. On the other hand, a full exercise of the masticatory function allows the complete expression of craniofacial development and could contribute to preserve intact a functional cognitive reserve through an adequate and necessary persistent stimulus to neurogenesis and to the differentiation of hippocampal neurons (11).

CONCLUSION

In light of the complexity and characteristics of cranial growth intimately correlated to the oral functions described, it appears clear that the treatment plan for malocclusions must be aimed primarily at rebalancing the altered functions. The purpose of orthognathic therapy in the growth phase cannot simply limited to the alignment of the teeth but must be aimed at restoring the balance of functions and consequently of bone development. For this, a logical and consistent treatment plan with the diagnosis is needed, avoiding mechanical and traumatic therapeutic means. In fact, the mechanical and traumatic forces during cranial growth can determine unpredictable and unpredictable effects due to the complexity and individuality of the structure. The restoration of oral functions can only take place if the forces expressed by the therapeutic device have the characteristics of self-regulating and intermittent physiological stimuli, allowing the self-repositioning of the mandible in the three planes of space in a position of greater structural balance. Only in this way, in addition to the repositioning of the teeth inside the arches, will it be possible to guarantee the recovery of the neuro-muscular coordination of the entire cephalic and neighboring districts and a harmonious, stable and lasting function for the future life of the little patient.

REFERENCES

1. Enlow DH, Bostwick III J. Handbook of Facial Growth. Plastic and Reconstructive Surgery. *Plastic and Reconstructive Surgery*. 1977;59(1):116-117.
2. Kuroda T. Evidence-based individualized orthodontic treatment: The future of orthodontics? *Journal of the World Federation of Orthodontists*. 2020;9(4):139-145. doi:10.1016/j.ejwf.2020.11.001
3. Ono T. Should the "envelope of discrepancy" be revised in the era of three-dimensional imaging?. *Journal of the World Federation of Orthodontists*. 2020;9(3):S59-S66. doi:10.1016/j.ejwf.2020.08.009
4. Dadgar-Yeganeh A, Hatcher DC, Oberoi S. Association between degenerative temporomandibular joint disorders, vertical facial growth, and airway dimension. *Journal of the World Federation of Orthodontists*. 2021;10(1):20-28. doi:10.1016/j.ejwf.2021.01.001
5. Mahdian A, Safi Y, Dalaie K, Kavousinejad S, Behnaz M. Correlation assessment of cervical vertebrae maturation stage and mid-palatal suture maturation in an Iranian population. *Journal of the World Federation of Orthodontists*. 2020;9(3):112-116. doi:10.1016/j.ejwf.2020.05.004

6. Grassia V, D'Apuzzo F, Ferrulli VE, Matarese G, Femiano F, Perillo L. Dento-skeletal effects of mixed palatal expansion evaluated by postero-anterior cephalometric analysis. *European Journal of Paediatric Dentistry*. 2014;15(1):59-62.
7. Frongia G, Piancino MG, Bracco P. Cone-Beam Computed Tomography. *Journal of Craniofacial Surgery*. 2012;23(4):1038-1043. doi:10.1097/scs.0b013e318252d5e1
8. Naini FB, Cobourne MT, Garagiola U, McDonald F, Wertheim D. Nasofacial angle and nasal prominence: A quantitative investigation of idealized and normative values. *Journal of Cranio-Maxillofacial Surgery*. 2016;44(4):446-452. doi:10.1016/j.jcms.2016.01.010
9. Moss ML. A theoretical analysis of the Functional matrix. *Acta Biotheoretica*. 1968;18(1-4):195-202. doi:10.1007/bf01556727
10. Piancino MG, Talpone F, Dalmasso P, Debernardi C, Lewin A, Bracco P. Reverse-sequencing chewing patterns before and after treatment of children with a unilateral posterior cross-bite. *The European Journal of Orthodontics*. 2006;28(5):480-484. doi:10.1093/ejo/cjl014
11. Piancino MG, Tortarolo A, Polimeni A, Bramanti E, Bramanti P. Altered mastication adversely impacts morpho-functional features of the hippocampus: A systematic review on animal studies in three different experimental conditions involving the masticatory function. Biagini G, ed. *PLOS ONE*. 2020;15(8):e0237872. doi:10.1371/journal.pone.0237872
12. Piancino MG, MacDonald F, Laponte I, Cannavale R, Crincoli V, Dalmasso P. Juvenile/Adolescent Idiopatic Scoliosis and Rapid Palatal Expansion. A Pilot Study. *Children*. 2021;8(5):362. doi:10.3390/children8050362
13. Persson, M, Magnusson, B, Thilander B. Sutural closure in rabbit and man: a morphological and histochemical study. *Journal of Anatomy*. 1978;125(Pt2):313-321.
14. Engstrom C, Kiliaridis S, Thilander B. The relationship between masticatory function and craniofacial morphology. II A histological study in the growing rat fed a soft diet. *The European Journal of Orthodontics*. 1986;8(4):271-279. doi:10.1093/ejo/8.4.271
15. Burn A, Herring S, Hubbard R, Zink K, Rafferty K, Lieberman D. Dietary consistency and the midline sutures in growing pigs. *Orthodontics & Craniofacial Research*. 2010;13(2):106-113. doi:10.1111/j.1601-6343.2010.01483.x
16. Alaqeel S, Hinton R, Opperman L. Cellular response to force application at craniofacial sutures. *Orthodontics and Craniofacial Research*. 2006;9(3):111-122. doi:10.1111/j.1601-6343.2006.00371.x
17. Rice PD. *Craniofacial Sutures: Development, Disease and Treatment. Frontiers of Oral Biology*. Vol 12. 1st ed. S. Karger; 2008:41-56.
18. Herring SW. *Mechanical Influences on Suture Development and Patency. Frontiers of Oral Biology.* Vol 12. 1st ed. S. Karger; 2008:41-56.
19. Opperman LA. Cranial sutures as intramembranous bone growth sites. *Developmental Dynamics*. 2000;219(4):472-485. doi:10.1002/1097-0177(2000)9999:9999<::aid-dvdy1073>3.0.co;2-f
20. Thilander B, Carlsson GE, Ingervall B. Postnatal development of the human temporomandibular joint I. A histological study. *Acta Odontologica Scandinavica*. 1976;34(2):117-126. doi:10.3109/00016357609026564
21. Hinton RJ. Changes in articular eminence morphology with dental function. *American Journal of Physical Anthropology*. 1981;54(4):439-455. doi:10.1002/ajpa.1330540402
22. Ingervall B, Carlsson GE, Thilander B. Postnatal development of the human temporomandibular joint II. A microradiographic study. *Acta Odontologica Scandinavica*. 1976;34(3):133-139. doi:10.3109/00016357609002560
23. Fuentes MA, Opperman LA, Buschang P, Bellinger LL, Carlson DS, Hinton RJ. Lateral functional shift of the mandible: Part I. Effects on condylar cartilage thickness and proliferation. *American Journal of Orthodontics and Dentofacial Orthopedics*. 2003;123(2):153-159. doi:10.1067/mod.2003.5
24. Muraglie S, Leonardi R, Aboulazm K, Stumpo C, Loreto C, Grippaudo C. Evaluation of structural skeletal asymmetry of the glenoid fossa in adult patients with unilateral posterior cross-bite using surface-to-surface matching on CBCT images. *The Angle Orthodontist*. 2020;90(3):376-382. doi:10.2319/061819-415.1
25. Piancino MG, Cannavale R, Dalmasso P, et al. Condylar asymmetry in patients with juvenile idiopathic arthritis: Could it be a sign of a possible temporomandibular joints involvement? *Seminars in Arthritis and Rheumatism*. 2015;45(2):208-213. doi:10.1016/j.semarthrit.2015.04.012
26. Bracco P, Debernardi C, Piancino MG, et al. Evaluation of the Stomatognathic System In Patients with Rheumatoid Arthritis According to the Research Diagnostic Criteria for Temporomandibular Disorders. *CRANIO®*. 2010;28(3):181-186. doi:10.1179/crn.2010.025

27. Piancino MG, Cannavale R, Dalmasso P, et al. Cranial structure and condylar asymmetry of patients with juvenile idiopathic arthritis: a risky growth pattern. *Clinical Rheumatology*. 2018;37(10):2667-2673. doi:10.1007/s10067-018-4180-5
28. Slavicek R. *The Masticatory Organ: Functions and Dysfunctions*. GAMMA Medizinisch-wissenschaftliche Fortbildung-AG; 2002.
29. Kamdar RJ, Al-Shahrani I. Damaging oral habits. *Journal of International Oral Health*. 2015;7(4):85-87.
30. Sum FHKMH, Zhang L, Ling HTB, et al. association of breastfeeding and three-dimensional dental arch relationships in primary dentition. *BMC Oral Health*. 2015;15(1):30. doi:10.1186/s12903-015-0010-1
31. Piancino MG, Kyrkanides S. *Understanding Masticatory Function in Unilateral Crossbites*. Wiley-Blackwell; 2016.
32. Piancino MG, Comino E, Talpone F, Vallelonga T, Frongia G, Bracco P. Reverse-sequencing chewing patterns evaluation in anterior versus posterior unilateral cross-bite patients. *The European Journal of Orthodontics*. 2011;34(5):536-541. doi:10.1093/ejo/cjr109
33. Frongia G, Ramieri G, De Biase C, Bracco P, Piancino MG. Changes in electric activity of masseter and anterior temporalis muscles before and after orthognathic surgery in skeletal class III patients. *Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology*. 2013;116(4):398-401. doi:10.1016/j.oooo.2013.06.008
34. Pirttiniemi P, Kantomaa T, Lahtela P. Relationship between craniofacial and condyle path asymmetry in unilateral cross-bite patients. *The European Journal of Orthodontics*. 1990;12(4):408-413. doi:10.1093/ejo/12.4.408
35. Pirttiniemi P, Raustia A, Kantomaa T, Pyhtinen J. Relationships of bicondylar position to occlusal asymmetry. *The European Journal of Orthodontics*. 1991;13(6):441-445. doi:10.1093/ejo/13.6.441
36. Fukushima-Nakayama Y, Ono T, Hayashi M, et al. Reduced Mastication Impairs Memory Function. *Journal of Dental Research*. 2017;96(9):1058-1066. doi:10.1177/0022034517708771
37. Piancino MG, Tortarolo A, Polimeni A, Cannavale R, Tonni I, Deregibus A. Adverse effects of the bite-raised condition in animal studies: A systematic review. *Archives of Oral Biology*. 2019;107:104516. doi:10.1016/j.archoralbio.2019.104516
38. Raucci G, Pachêco-Pereira C, Elyasi M, d'Apuzzo F, Flores-Mir C, Perillo L. Predictors of postretention stability of mandibular dental arch dimensions in patients treated with a lip bumper during mixed dentition followed by fixed appliances. *The Angle Orthodontist*. 2016;87(2):209-214. doi:10.2319/051216-379.1
39. Raucci G, Pachêco-Pereira C, Grassia V, d'Apuzzo F, Flores-Mir C, Perillo L. Maxillary arch changes with transpalatal arch treatment followed by full fixed appliances. *The Angle Orthodontist*. 2014;85(4):683-689. doi:10.2319/070114-466.1
40. Raucci G, Elyasi M, Pachêco-Pereira C, et al. Predictors of long-term stability of maxillary dental arch dimensions in patients treated with a transpalatal arch followed by fixed appliances. *Progress in Orthodontics*. 2015;16(1). doi:10.1186/s40510-015-0094-9
41. Cerutti-Kopplin D, Feine J, Padilha DM, et al. Tooth Loss Increases the Risk of Diminished Cognitive Function. *JDR Clinical & Translational Research*. 2016;1(1):10-19. doi:10.1177/2380084416633102
42. G. Dipalma, G, A. D. Inchingolo, A, A. Mancini, A, et al. Oro-facial pain in Chiari type 1 malformation. *Journal of Biological Regulators and Homeostatic Agents*. 2022;36(2(S3)):21-30.
43. Scarano A, Barros RRM, Iezzi G, Piattelli A, Novaes AB. Acellular Dermal Matrix Graft for Gingival Augmentation: A Preliminary Clinical, Histologic, and Ultrastructural Evaluation. *Journal of Periodontology*. 2009;80(2):253-259. doi:10.1902/jop.2009.080326
44. Scarano A, Piattelli A, Polimeni A, Di Iorio D, Carinci F. Bacterial Adhesion on Commercially Pure Titanium and Anatase-Coated Titanium Healing Screws: An In Vivo Human Study. *Journal of Periodontology*. 2010;81(10):1466-1471. doi:10.1902/jop.2010.100061
45. G. Dipalma, A. D. Inchingolo, A. Mancini, et al. Augmented and Virtual Reality as Training Tool for Maxillofacial Surgeons and Neurosurgeons: Is It the Future? *Journal of Biological Regulators and Homeostatic Agents*. 2022;36:81-89.
46. Corsalini M, Daniela DV, Biagio R, Gianluca S, Alessandra L, Francesco P. Evidence of Signs and Symptoms of Craniomandibular Disorders in Fibromyalgia Patients. *The Open Dentistry Journal*. 2017;11(1):91-98. doi:10.2174/1874210601711010091
47. Inchingolo F, Pacifici A, Gargari M, et al. CHARGE syndrome: an overview on dental and maxillofacial features. *European Review for Medical and Pharmacological Sciences*. 2014;18(15):2089-2093.
48. Di Venere D, Laforgia A, Azzollini D, et al. Calcification of the Atlanto-Occipital Ligament (Ponticulus Posticus) in Orthodontic Patients: A Retrospective Study. *Healthcare*. 2022;10(7):1234. doi:10.3390/healthcare10071234.