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AN OVERVIEW OF ORTHODONTIC FUNCTIONAL ANALYSIS

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Abstract: Functional analysis is mainly concerned with the functional units of the masticatory system. Given the gradual development and indirect accumulative effect of occlusal disharmonies, functional analysis could be considered the only method that can demonstrate malocclusions and their possible connections with functional disturbances and disorders. Thus, analysis of the functional units of the stomatognathic system should follow the clinical examination of the various components of the craniofacial complex in static and dynamic relationship, to achieve a comprehensive orthodontic treatment. Assessment of the temporomandibular joints (TMJs) is one of the major elements of the functional analysis, and one of the long-term objectives of orthodontic treatment is to obtain an optimal function and health of the TMJs and masticatory system. Therefore, many studies discuss the condition of the TMJs in the pre- and post-treatment phases, regarding the disorders that may be present or will develop in the future. In this context, the objective of this literature overview is to explain the need of the functional analysis in modern orthodontics and the parts and components involved in the examination of the functional units of the stomatognathic system.

Keywords: Temporomandibular joints, Temporomandibular disorders, Functional analysis, Orthodontics

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1. Introduction

In orthodontics, the diagnosis should extend beyond a static evaluation of the teeth and their supporting structure to an examination of the functional units of the stomatognathic system (Eschler, 1965) particularly, the masticatory system (Mohl and Aj, 1977). The functional analysis should follow the clinical examination of various components of the craniofacial complex in both the static and dynamic relationship of the stomatognathic system.

In order to plan an adequate orthodontic treatment, the functional analysis has a great importance, and should not be considered only as a method to determine the etiology of malocclusion. Moreover, taking into consideration the gradual development and indirect accumulative effect of occlusal disharmonies, it could be considered the only method that can demonstrate occlusal disturbances and their possible connections with functional imbalances and disorders. Many of the conditions may appear harmless at first, but may lead to secondary changes that result in deterioration of the dentition, indicating the importance of the functional analysis.

One of the long-term objectives of orthodontic treatment is to obtain optimal function and health of the temporomandibular joint (TMJ) and masticatory system (Tallgren et al., 1979). Thus, assessment of the TMJ is a major component of the functional examination and analysis. Many studies discuss its condition in the pre- and post-treatment phases, regarding the disorders that may be present or will develop in the future. For instance, Fränkel and Fränkel (1983) observed patients with problems and suggested that orthodontic treatment may induce TMJ disorders. Conversely, Larsson and Ronnerman (1981), as well as Janson and Hasund (1981), concluded that patients subjected to orthodontic treatment are not prone to temporomandibular disorders in later life.

A recent study by Denes et al. (2018) demonstrated that using a bite-block appliance leads to weak masticatory muscle function at all regions of the condylar process. Conversely, according to Maillard et al. (2017), neuromuscular molding appliances have positive surgical, aesthetical, functional and socio-economic effects on the patients undergoing orthodontic treatment. The benefits are especially apparent in the cases of unilateral clefts of the lip and palate treatment before the primary repair surgeries (Maillard et al., 2017). Hence, the need for more understanding of the role of the neuromuscular environment in the orthodontic treatment and the surrounding soft tissue equilibrium on the teeth locations.

The aim of this review of literature is to describe the functional analysis and describe the affects and benefits in orthodontic treatment.

2. Treatment Objectives

The functional analysis objective is examination and evaluation of the functional components of stomatognathic system mainly the jaws

- Examination of the postural rest position and

maximum intercuspation
- Examination of the path of closure
- Examination of the TMJs
- Examination of the orofacial function

3. Examination of Postural Rest Position and Maximum Intercuspation

Historically, the mandibular rest position has been considered as a reference position (Turrell, 1972). Although mandibular posture is a contentious topic that defines a distinct definition, it is defined as generally the unforced position assumed by the mandible, when a person is relaxed with the head upright (Thompson, 1949). The rest position can be obtained either through verbal instruction and observation (Michelotti et al., 1997) or by monitoring muscle activity, but different methods have been shown to induce variations in the recorded rest position of the same subjects (Peterson et al., 1983).

Various methods have been developed for measuring and recording of the rest position, but typically it is measured based on external soft tissue landmarks (Yoo, 1989) or by manual intraoral distances between the incisors (Ormianer and Gross, 1998). Kinesiography can also be used to establish the rest position. However, the measurements of the rest position taken at the incisors region or other anterior facial structures may not provide complete information about the position of the mandible (Michelotti et al., 1997).

The study by Travers et al. (2000) showed that there was little or no correlation between incisor and condylar movement during the mouth opening, indicating that incisor movement has poor predictive value for changes in the condylar position (Ferrario et al., 1996). Considering that condylar translation occurs even during the initial mouth opening when subjects move into the rest position, changes in condylar position might be expected.

Mandibular rest position was initially believed to be established at birth (Brodie, 1941) and maintained throughout life (Thompson and Brodie, 1942). Nevertheless, subsequent research suggests that rest position is altered by several factors, including occlusal interferences, temporomandibular dysfunction, psychosocial stress, nasal obstruction, and head position (Odeh et al., 1995).

The postural rest position of the mandible can be defined as the position at which the synergists and the antagonists of the orofacial system are balanced dynamically and in their basic tonus. The interocclusal clearance or freeway space describes the space between the upper and lower jaws, at the postural rest position, which is usually 3 mm in the canine region (Odeh et al., 1995).

The primary goal of the examination of postural rest position and maximum intercuspation in the functional analysis is to assess the mandibular position as determined by the musculature. The rest position should be measured with the patient relaxed and seated upright with the back unsupported. The head is oriented, by making the Frankfort horizontal parallel to the floor (Graber, 1993).

The postural position is useful in the differential diagnosis of deep bite cases. In true deep bite cases, in which increased freeway space are detected, infraocclusions of the posterior teeth are observed, and treatment by extrusion of the posterior teeth is indicated. Conversely, in the pseudo-deep bite cases with normal freeway spaces, the bite opening by intrusion of the anterior teeth is recommended.

As mentioned above, there are various methods to establish the postural rest position, as exemplified below:

- Phonetic method: Uses the patient's pronunciation of consonants like the letter (M) or words that contain these letters, where the mandible usually returns to the rest position after the exercise (Eschler 1965).
- Command method: The patient performs selected functions, like swallowing or licking his/her lips, at the end of which the mandible spontaneously returns to the rest position (Eschler 1965).
- Non-command method: The patient is distracted by engaging in general subject conservation, to obtain the relaxation of the musculature where the mandible reverts to the postural rest position (Eschler 1965).
- Combined method: A combination of the previous three procedures, is considered the most suitable for the functional analysis in children. This protocol can be performed by both observing the patient while swallowing and speaking. Furthermore, to relax the musculature, the tapping test can be used (Eschler, 1965).

In the tapping test, the mandible is opened and closed with constantly increasing frequency, by holding the chin by the index and the thumb fingers until the musculature is relaxed, which can be further confirmed by tapping the submental muscle (Eschler, 1965).

The rest position can be determined regardless of the method used, by checking the mandible position extra orally. The patient is told not to change the jaw, lip or tongue position and then by parting the lips, the maxillomandibular relationship and the freeway space can be determined (Mohl and Aj, 1977).

4. Path of Closure Examination

Evaluation of functional symmetry of the craniofacial complex usually involves the patterns of jaw movements and the activities of masticatory muscles (Abekura et al., 1995, Ferrario et al., 2000). Surface electromyography is a widely used method of monitoring jaw-closing muscle activity (Dahlström, 1989), despite some method problems in recording surface electromyographic (EMG) activity (Ferrario et al., 1991). Ultrasound scanning

enables dynamic visualization of the muscles of the head and neck (Emshoff et al., 2002, Kiliaridis et al., 2003), and it is an accurate and rapid method for measuring the thickness of superficial muscles such as the masseter and temporalis, without known adverse effects (Dahlström, 1989). A significant positive correlation was found between the masseter muscle thickness measured by ultrasonography and its maximal EMG activity in individuals with normal occlusion (NOCCL) (Georgiakaki et al., 2007).

The path of closure is the movement of the mandible from the rest position to the full occlusion. The mandible is typically closed by a simple rotary type movement, in which the condyle acts as the center of rotation (Preiskel, 1965). The path of closure is found to be abnormal in some conditions, because of the occlusal interference in some patients. Similar to conditions during mandibular sliding, the amount of rotation is analyzed in all three planes of space (Preiskel, 1965):

- Sagittal plane: When viewed from the sagittal plane, it is valuable to know the precise type of the mandibular movement from the rest position to occlusion (whether it is a pure hinge movement, partly hinge with anterior sliding or partly hinge with posterior sliding component (Turrell 1972).
- Vertical plane: In the vertical plane, it is of significant value to determine the treatment potential when using the functional appliance in treatment of deep bite cases, which can be well-observed in the true overbite cases. These can be treated with a functional appliance and have a favorable prognosis. In contrast, pseudo-deep bite problems have a poor prognosis with these devices (Turrell 1972).
- Transverse plane: The clinical examination of the transverse functional relationship can be achieved by assessing the path of closure of the mandible from postural rest to habitual occlusion. For this, observations are performed of the midline position of the mandible, during the mandibular movement from the postural rest to occlusion (Lemmer, Lewin et al. 1976).

5. TMJ Examination

The TMJ, with its sliding nature, joint surface, and fibrocartilage disc, primarily differs from other joints, by the type of its functional movement. The disc is joined to the condyle by ligaments that allow rotation on the condyle during translational jaw movements (Solow and Tallgren, 1976). The posterior border of the disc is secured by a highly vascular attachment with elastic fibers, while a muscle (lateral pterygoid) secures the anterior border. The sides of the disc are attached to the medial and lateral poles of the condyle (Sonnesen and Health Effects. Cardiff 2014).

During jaw movements, the condyle and the disc slide in the temporal fossa. The sliding movement enables the sideways movements of the jaw during chewing and its wide opening. The disc performs several functions, such as cushioning and distributing joint loads, promoting joint stability during chewing, facilitating lubrication and nourishment of the joint surfaces, preventing gross degenerative changes in the condyle and fossa, and promoting normal growth of the mandible (McNamara and Carlson, 1979).

During chewing, mandible elevation and lowering movements are centrally determined and modulated by receptors found in the periodontium, temporomandibular joints, tongue, mucosa, tendons, and muscle spindles of elevator muscles, all of which play an important role in mastication and the longevity of the dentition (Bosman et al., 2004). Accordingly, alterations in jaw rotation in subjects with different facial length could result in both variations of muscular force and different stimulation of muscle spindles of elevator muscles (Miralles et al. 2002).

The examination of the TMJs and associated musculoskeletal structure should be included in the functional analysis, to establish the presence or absence of any abnormal function and thereby select the appropriate treatment. The clinical examination of the TMJs should include auscultation and palpation of the TMJs and the muscular system associated with the mandibular movement, as well as the functional analysis of the mandibular movement (McNamara and Carlson, 1979). Any deviation in the opening and closing movement of the mandible should also be evaluated, for example, lateral deflection of the mandible caused by anterior disc dislocation (Lindauer et al., 1995).

Typically, there are two abnormalities regarding the opening and the closing of the mouth. “Close lock” occurs with the anterior displacement of the articular disc, causing interference with the opening of the oral cavity and resulting in a situation where the patient cannot open their mouth. In contrast, in the event of “open lock”, the patient cannot close their mouth, due to posterior displacement of the articular disc, which may not permit the condyle to return to its position in the fossa (McNamara and Carlson, 1979).

The patient should also be examined for any sign of bruxism (teeth grinding) and jaw clenching, which is typically a nocturnal activity. Complaint of a headache on awakening may be a good indication. Ultimately, the patient should be left with a healthy masticatory system and good function in centric position. Hence, the patient’s occlusion should be analyzed during various border excursion of the mandible for any premature or deflective contact (Minagi et al., 2000). The functional analysis of the TMJ is done by evaluation the opening and the closing movement of the mandible, as well as it is protrusive, retrusive, and lateral excursions.

Also, it should not that Even when orthodontic treatment needs and TMD signs and symptoms are present, stronger bite force can still be observed in males and in subjects with smaller anterior facial heights and wider

facial width (de Lima Lucas et al., 2017).

6. Orofacial Function Examination

A thorough analysis of the stomatognathic system is a part of modern orthodontic diagnosis and treatment planning. Any deviation in the normal function may be a primary etiological factor in the development of malocclusion (Gonzalez and Manns, 1996). Notably, adaptive functional activity is the result of the deformation of the structure that may persist even after the disappearance of the original causal factor (Odeh et al., 1995).

In a study performed by Regola et al. (2017) the fallowing conclousion was obtined that children with slight-to-borderline orthodontic treatment needs presented functional disorders of the stomatognathic system, such as hyperactivity in almost all of the muscles analyzed, and lower masticatory performance (Rugh and Drago, 1981).

6.1. Tongue Evaluation

The clinical assessment of the tongue function contributes to the thorough examination of the stomatognathic system. One of the abnormal functions of the tongue to consider is the tongue thrust. The reason is that tongue thrust plays a key role in the etiopathogenesis of malocclusion, either as a primary causative factor as a result of retained infantile swallowing or other abnormal pressure habits or as a secondary action, due to an existing abnormal skeletal or dental alveolar pattern (Gonzalez and Manns, 1996).

The tongue posture should also be evaluated and examined clinically. While the mandible is in the rest position, the shape and size of the tongue should be noted and recorded, which could be narrow and long, protracted or retracted, spread latterly and shortened flat or arched.

6.2. Swallowing Evaluation

During evaluation of swallowing, the normal (functionally balanced) swallow should occur without contracting the muscles of facial expression. If an abnormal swallow is present, even though the tongue is normal and the teeth are in contact, the causative factor may be retained infantile swallow or tongue thrust (Tueller, 1969).

Under normal development pattern, the functionally balanced swallow is established between 2 and 4 years of age. If the visceral or infinite swallow is present during the first few years of life and it is not gradually replaced by the mature swallowing, retention of the infantile swallow develops, which can lead to tongue postural and functional changes (Lund et al., 1970).

6.3. Speech Evaluation

A full assessment and observation of the speech are of significant importance, due to the variety of dysfunctions or structural defects involving the palate, tongue, lips, and dentition. Severe malocclusion in some patient interferes with the normal production of certain sounds, thereby making the pronunciation of some words difficult or impossible (Rugh and Drago, 1981).

6.4. Lip Evaluation

Lips are assessed for configuration, function, and presence of dysfunction. The lip dysfunction can be observed when the patient is speaking or swallowing (Lindauer et al., 1995).

6.5. Respiration Evaluation

The clinical examination should incorporate an evaluation of respiration to determine the mode of breathing, which can help to recognize the underlying problem of malocclusion, as seen in the underdeveloped maxilla in the case of mouth breathing. An impaired nasal breathing represents a dysfunction of the orofacial musculature and interferes with the normal development of the dentition and orthodontic treatment (Özbek et al., 1998). Identification of the respiratory issue, if present, aids in providing the correct treatment.

The importance full and complete evaluation of the respiration were demonstrated by Anitua et al. (2017) to determine the necessary amount of mandibular advancement as a method to treat of obstructive sleep apnea.

The research done by Iwasaki et al. (2017) presented that large negative inspiratory pharyngeal airway pressure due to nasal obstruction in children with Class II malocclusion may be related to their retrognathia.

7. Conclusion

The main conclusions of the study;

- Functional analysis should be performed, including a complete examination of the jaw movement and determination of the TMJ position, in addition to a thorough assessment of the oral function, muscles, and structures.
- The analysis of the functional behavior, including swallowing, speech, phonation, and respiration carry major importance for patients attending normal or myofunctional orthodontic therapy and having preoperative orthodontic preparation for orthognathic surgery.
- TMJ examination should be done during the opening and closing movements of the jaws, to establish the presence or absence of any functional discrepancy that could limit the outcome or interfere with the treatment type.
- Orofacial function evaluation, which includes the assessment of the speech, phonation, lip closure, and swallowing are pivotal as abnormal function of these structures leads to an increased relapse incidence if insufficient care is taken.

Author Contributions

All authors have equal contribution and all authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

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