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The masticatory system - an overview

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SUMMARY

Masticatory muscle physiology has been evaluated mostly from electromyographic recordings. However, electromyography coupled with jaw -tracking devices has provided much more information of the correlation between jaw movements and muscle activity.

Knowledge of how the mandible moves during mastication has greatly influenced procedures in clinical dentistry.

The aim of this overview is to give basic description of the classical studies of the physiology, function and neural control principles of the mastication.

Mastication is the action of breaking down of food, preparatory to deglutition. This breaking-down action is highly organized complex of neuromuscular and digestive activities.

The duration and forces developed in the power stroke vary within and between individuals and for the type of the food being chewed.

It has been suggested that the observation of masticatory movements may be of diagnostic value for assessing disorders of the stomatognathic system, but there is not clear evidence to show significant differences.

The action of masticatory muscles during chewing varies between subjects in amplitude, onset timing, and duration of the chewing cycle

Since tooth guidance has an enormous influence on muscle activity during chewing and swallowing, it is advisable to make restorations compatible with the functional movement patterns of the patient rather than expect the patterns of the mastication to adapt to the new made restorations.

Key words: mastication, chewing movement, chewing muscles

INTRODUCTION

The masticatory system is a functional unit composed of the teeth; their supporting structures, the jaws; the temporomandibular joints; the muscles involved directly or indirectly in mastication (including the muscles of the lips and tongue); and the vascular and nervous systems supplying these tissues. Functional and structural disturbances in any one of the components of the masticatory system may be reflected by functional or structural disorders in one or more of its other components (1). However, there is a lot of evidence that the masticatory system has ability to the wide range of adaptive modalities. These adaptations can be functional and/or structural and may respond to transient and/or permanent demands. Therefore, this system, like any biological system, cannot be viewed as a rigid and immutable (2).

Masticatory muscle physiology has been evaluated mostly from electromyographic recordings. However, electromyography coupled with jaw -tracking devices has provided much more information of the correlation between jaw movements and muscle activity.

Knowledge of how the mandible moves during mastication has greatly influenced procedures in clinical dentistry. Historically, an understanding of mandibular movement was considered important in removable prosthodontics. Later, this information was used in the design and setting of articulators, and in the design of the dentures and denture teeth themselves. Today the importance of jaw movements has become apparent in fixed prosthodontics, periodontics, orthodontics, and in the diagnosis and treatment of pain disorders of the masticatory system (3). The most important reason why dentists maintain and replace missing teeth should be to provide patients with good masticatory abilities. Therefore, it is important that dentists know how mastication normally occurs. This knowledge should ensure that dental procedures improve, rather than reduce, patient's functional abilities.

The aim of this overview is to give basic description of the classical studies of the physiology, function and neural control principles of the mastication.

MASTICATORY FUNCTION

Mastication is the action of breaking down of food, preparatory to deglutition. This breaking-down action is highly organized complex of neuromuscular and diges-

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tive activities that, in normal individuals, integrate the various components of the masticatory system, such as the teeth and their investing structures, the muscles, the temporomandibular joints, the lips, the cheeks, the palate, the tongue, and the salivary secretions. The object of chewing is to crush, triturate and mix food with saliva, so that food can be transported by deglutition down the digestive canal (4).

The most important muscles for this purpose are temporal (anterior and posterior), the masseter (superficial and deep), the medial pterygoid, the lateral pterygoid (superior and inferior), and the digastric muscles. The trigeminal motor nucleus of motoneurons innervating the jaw muscles lies across the midline of the brainstem. However, mastication involves far more muscles than these "muscles of mastication" innervated by the trigeminal nerve. Synergestic movements of muscles innervated by facial and hypoglossal nerves are equally important (5).

The masticatory sequence is the whole set of movements from ingestion to swallowing. It is made up of masticatory cycles that change in form as the food is gathered, moved backward to the molar teeth, then broken down and prepared for swallowing (6). It is possible to distinguish between cycles which occur at the beginning of the masticatory sequence and form the preparatory series of movements, cycles of particle reduction and cycles related to preswallowing (6). The cycles of reduction are intermediate in duration, longer than the preparatory cycles, but shorter than the preswallowing ones.

Differences in type, number, and size of food particles appear to influence almost all the parameters of mastication. The length of the masticatory sequence is short for soft foods and long for those that are hard or tough (7,8).

NEUROLOGICAL CONTROL

Jaw movements are among the most complex and unique movements performed by the human body. The mandible, unlike any other bones in the human body, is slung between two nearly symmetrical joints, which are close to being the mirror image of one another. Each muscle involved in the control of mastication has its counterpart on the opposite side of the jaw (9).

To create precise mandibular movements, inputs from various sensory receptors must be received by the central nervous system through afferent nerve fibers. The brain assimilates and organizes these inputs and elicits appropriate motor activities through the efferent nerve fibers. These motor activities involve the contraction of some muscle groups and the inhibition of others. Chewing is a subconscious activity, yet can be brought to conscious control at any time (10).

The coordination and rhythmicity of mastication has been attributed to the alternate activation of two simple brain stem reflexes. These are the jaw opening reflex, activated by tooth pressure or tactile stimulation of wide areas of the mouth and lips, and the jaw-closing reflex, which follows stretching of the elevator muscles during opening (11,12). The introduction of a food bolus into the mouth was thought to initiate a self-perpetuating cycle by producing jaw opening, and the consequent stretching of the elevator muscles would produce jaw closure on the bolus, again producing jaw opening by stimulation of periodontal and soft tissue receptors (13). The same authors found that in rabbits the timing of rhythmic chewing occurs within the brainstem. They suggested that mastication is controlled by a pattern generator brought about by reverberating circuits within the brainstem and that this patterning can be activated by adequate inputs from higher centers or from feedback through sensors in the oral cavity.

The control of mastication is dependent in large part on sensory feedback, which consists of epithelial mechanoreceptor afferents, periodontal afferents, temporomandibular joint afferents and muscle afferents. Sensory feedback may explain the coordination of the tongue, lips, and jaws to move the food around, the reason why different foodstuffs influence the pattern of masticatory movement, or the abrupt changes from cycle to cycle (6). While the cortex is the main determiner of action, centers in the brain-stem maintain homeostasis and control normally subconscious body functions (10).

Within the brain-stem is a pool of neurons - a central pattern generator (CPG) - that controls rhythmic muscle activities (13). The neurons can be activated by adequate inputs from higher centers or from the oral cavity (6,13), and it is responsible for the precise timing of activity between synergetic and antagonistic muscles, so that specific functions can be carried out (10). Sensory feedback interact with the control system at several levels to adapt the rhythmic program to characteristics of the food. This feedback is also a source of the variability in masticatory movements (6). Once an efficient chewing pattern is found, it is learned and repeated. This learned pattern is called a muscle engram. Chewing therefore can be thought of as an extremely complex reflex activity. The brain-stem also contains other areas, such as the reticular system, the limbic system and the hypothalamus, that have influence on masticatory function. These structures can modify the response of the cortex to any given stimulus, modify motor neuron activity, and even initiate irrelevant muscle activity (10). Thus, features of mastication can be programmed by the brain stem in the absence of sensory inputs, but such movements would be highly inefficient and even dangerous to the masticatory system (6).

NORMAL MASTICATORY MOVEMENTS

The earliest human jaw reflex is the jaw-opening reflex, which may be produced by mechanical stimulation of the lip (14). The explanation is that the digastric neurons differentiate before those of the jaw closing muscle neurons in the fetus. Jaw closing occurs passively at first. After birth it is possible to observe functions such as crying, sucking, swallowing, and scowling, but not chewing. Chewing must be learned, and occurs only after tooth eruption. It is possible that periodontal ligament receptors and their stimulation are essential for this learning process (15).

Chewing becomes well coordinated around 4-5 years of age, by which time the primary teeth have erupted (16). Different investigations have shown that the pattern of masticatory movements varies considerably from one individual to another (17-19). It is believed that each individual has a characteristic basic pattern of masticatory movement. However, consecutive cycles are never exactly alike (17). Significant differences in chewing are presented between men and women (18,20), as well as between young and elderly people (21).

The wide variation within and between individuals of the masticatory movements is explained by the infinite variation of afferent inflow during natural chewing (16).

The masticatory envelope is usually described as a "tear-drop shape" with a slight displacement at the beginning of the opening phase (22). This means that the opening movement rarely goes straight down. In most cases it deviates to the chewing side (16,23). The maximum extent of vertical and lateral movement in normal masticaton is about half of the maximum vertical and lateral movement possible. When a subject deliberately chews on the right side, the jaw follows a cyclic pathway is a clockwise direction, and chewing on the left side is associated with movement in a counterclockwise direction (24). Neill & Howell (23) reported that 75% of chewing strokes describe a regular cyclic pattern. Less than 6% of the strokes began with a vertical opening. The most lateral point of the chewing cycle is situated about midway through the closing cycle for grinding movements, but is lower for chopping movements (16).

Usually the closing phase is lateral to the opening phase although often this relationship is reversed, and the closing phase passes medial to the opening movement, i. e., a reversed masticatory stroke takes place (16).

Neill & Howell (23) showed that in the sagittal plane approximately half of the subjects had the opening stroke anterior to the closing stroke. The angulation of the sagittal pathway was normally directed upward and backward, reflecting the rotational element in mandibular opening.

The character of the food influences the chewing pattern (25,26). The opening length depends on the size and the hardness of the food bolus (27). As the food is softened, the lateral and the vertical extend of the jaw movements decrease (19,28).

The hardness of the food also has an effect on the number of chewing strokes necessary before a swallow is initiated. The harder the food, the more chewing strokes are needed (29).

Each chewing cycle has duration of about 700 ms and tooth contact of about 200 ms (1).

EMG ACTIVITY DURING MASTICATION

During mastication the relationship between muscle actions is generally similar between subjects (30).

During the chewing cycle, muscle activity begins from the static position of maximum intercuspation, and initially occurs in the ipsilateral inferior head of the lateral pterygoid muscle approximately halfway through the tooth contact period. This activity is shortly followed by activity in the inferior head of the contralateral pterygoid muscle. These two muscles are active through the entire duration of the opening phase (31). The digastric muscles are also active during the opening phase and contribute mainly to a rotational component of mandibular opening. The opening phase ends when the activity in the two inferior heads of the lateral pterygoid muscles and digastric muscles ceases. Correspondingly an activity in the medial pterygoid muscle is initiated (31). This muscle controls the upward and lateral position of the jaw. The medial pterygoid is much more active in wide strokes than in narrow chopping strokes, and during early closing (32). The electromyographic activity ceases during the intercuspal phase. However, during narrow strokes both the ipsilateral and the contralateral medial pterygoid muscles are active at the onset of intercuspation (32). At the beginning of the closing phase the ipsilateral temporal muscle contracts first, and thereafter the contralateral temporal muscle and both masseter muscles become active simultaneously. The electromyographic activity in these muscles is very low, but it gradually increases and reaches a peak at the end of the closing movement during the occlusal level phase (17).

During the ingestion and mastication of a piece of hard food, the cyclical EMG activity in the jaw closing muscles generally decreases with the progressive comminution and softening of a single small piece of food. The force generated by the jaw muscles depends on the food consistency (5).

Perioral facial muscles, such as the buccinator, the superior and inferior orbicularis oris, the triangularis and the inferior quadratus labii muscles are active during normal mastication. Their activity is predominant during the period in which the mandible is lowered, is out of phase with that of the master muscle, and overlaps in part with that of the digastric muscle. The activity starts in the first part of the opening phase of the chewing cycle, and terminates in the closing phase, before the masseter activity leading to the clenching phase reaches its peak (33).

Electromyographic records taken before the loss of posterior teeth, after the loss of posterior teeth with only anterior teeth present, and after insertion of dentures following the loss of posterior teeth, show that the facial and circumoral muscles become very active in mastication, whereas there is minimal masseter activity. Normal muscle activity resumes following insertion of well-fitting dentures (34).

Besides the masticatory muscles, a number of head and neck muscles actively and passively participate in the act of mastication, and a muscle activity is always guided toward the optimum functional result (1).

MASTICATORY FUNCTION IN INDIVIDUALS WITH TEMPOROMANDIBULAR DISORDERS

It has been suggested that the observation of masticatory movements may be of diagnostic value for assessing disorders of the stomatognathic system (35-38).

Many authors (39-41) reported that certain aspects of the chewing patterns of temporomandibular disorders (TMD) patients were different from controls. On the contrary, Feine et al. (42) were not able to show significant differences in chewing movements between small groups of healthy subjects and TMD-patients. Kuwahara et al. (43) showed that specific chewing patterns appeared to be associated with specific TMJ disorders. Yet, the chewing movements of patients with myofascial pain had the same pattern as healthy subjects. Thus, people with pain in the masticatory muscles or with joint sounds may have normal mandibular range of movement (44).

There is no strong evidence that any particular chewing feature is charactiristic of TMD-patients (45).

CONCLUSIONS

Mastication is oral motor behavior reflecting central nervous system commands, and many peripheral sensory inputs to modulate the rhythmic jaw movements.

The action of masticatory muscles during chewing varies between subjects in amplitude, onset timing, and duration of the chewing cycle. However, it is possible to recognize similarity between muscle actions. These wide variations (within and between individuals) can be explained by differences related to individual occlusal contact features and specific musculoskeletal morphology.

Mandible moves not only vertically during mastication, but also anteroposteriorly and laterally. These horizontal movements are most important in the reconstruction of missing teeth.

In a chewing cycle the approach to tooth contact is relatively reproducible, it is learned and programmed, but it can be altered by loss of teeth or changed by restorations.

Since tooth guidance has an enormous influence on muscle activity during chewing and swallowing, it is advisable to make restorations compatible with the functional movement patterns of the patient rather than expect the patterns of the mastication to adapt to the new made restorations.

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