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Adaptation of healthy mastication to factors pertaining to the individual or to the food

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Abstract

Mastication is a physiological process controlled by the central nervous system and modulated by inputs from the mouth. Both the intrinsic characteristics of the subject and the extrinsic characteristics of the chewed food are responsible for variations of the masticatory function. Age, gender and dental state constitute the most studied intrinsic factors whereas hardness, rheological characteristics such as plasticity or elasticity, and food size are the better known extrinsic factors. These factors cause physiological adaptations which can occur during individual cycles or the whole sequence of mastication. Electromyographic and jaw movements (kinematic) recordings are commonly used to study mastication, from which, several variables can be measured. Vertical and lateral amplitudes and, velocities of jaw movements, are only given by kinematic recordings. Bioelectrical activities per cycle or per sequence are closely linked to masticatory forces and are measured from electromyographic recordings. Number of cycles, sequence duration and masticatory frequency can be measured from both types of recordings. The objective of this review is to provide an overview of the variations of the measured masticatory variables that occur when mastication adapts to changes in characteristics of the individual or the food.

Keywords: Rheological behaviour; Model food; Elastic or plastic food texture; Masticatory adaptation

1. Introduction

A sequence of mastication begins with the introduction of a piece of food into the mouth and finishes with the deglutition of the food bolus. Each sequence is made by a succession of chewing cycles. Each cycle is formed by one jaw-opening followed by one jaw-closing movement. Because of the regular succession of cycles, rhythm is a major characteristic of mastication. The rhythm of mastication is generated by a brain stem central pattern generator (CPG) [1], which activates a motor program coordinating the activities of the jaw, tongue and facial muscles [2]. The masticatory program adapts its output to the properties of the food being chewed, including the size of the food sample introduced in the mouth, its hardness and other physical properties that cause the sensations of texture [3–11]. Adaptation of the motor program also occurs continuously throughout the chewing sequence as the food properties are modified by mastication. The food acts as a stimulus exciting several types of receptor (periodontal, muscle spindle, mucosal). The sensory messages, which are conveyed to the brain stem, are used in one or several feedback loops allowing continual adaptation of the motor activities to the mechanical properties of the food which are progressively changing during the sequence [2,12]. This leads to the formation of a bolus ready-to-swallow. Finally, adaptation of the motor program is also needed throughout an individual's life to cope with the changes that occur as a result of ageing and tooth loss.

The aim of this review is to describe the variations of both the jaw movements and the masticatory muscle activities observed while different groups of individuals are chewing different types of foods. The factors that induce variations in the masticatory parameters are related to either the food (sample size, hardness or rheological behaviour) or the individual (age, gender or dental health). They will be called extrinsic and intrinsic factors respectively. The term "rheological behaviour"

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refers to the science of rheology. This science is a branch of physics that studies the stress/strain relationship of materials. It describes properties such as elasticity, plasticity or brittleness. Other factors such as the time of day, appetite, liking/disliking of food, flavour, previous experiences, education and many others that also modulate the masticatory function will not be considered in this article.

2. Recording mastication

Many methods can be used to record masticatory function. Most frequently, mastication is monitored by kinematic and electromyographic (EMG) recordings. The former gives information about jaw movements and the later follows bioelectrical activities of the masticatory muscles which are known to be closely related to the forces developed during the course of mastication [13,14]. The use of videography to record mastication has been validated in different groups of subjects [15,17]. It offers the advantage of being less intrusive than EMG or kinematic recordings which is particularly important for anxious or other special patients. It is also easier to use in a dental clinical setting and it gives information about the soft tissues functions such as lip closure [16,17]. The function of the jaw muscles during chewing can also be inferred by recording the force during chewing [see Ref. [18]] or during maximal biting [19]. The function of the tongue and other soft tissues was recently observed with videofluorography [20], by observing the orientation of non edible material in the mouth [21] or by observing the mixing or positioning of differently colored materials [22,23]. Recently, ultrasonic echo-sonography was used to observe the soft tissues [24]. All these recordings illustrate the rhythmical nature of mastication. During one sequence, the recordings often show intermediate and final deglutitions as well as changes of the masticatory side (i.e. from left to right or vice versa) (Fig. 1). They also indicate that a clearance stage exists which starts after the final deglutition and is characterized by non periodic muscle activity [25,26].

3. Grinding and crushing the food

At the end of the sequence, the food bolus must be smooth, deformable and cohesive [7,11]. This is required to facilitate harmless passage of the bolus through the aero-digestive crossing and then through the esophagus. To obtain such a food bolus, the food must be transformed into many small-sized particles bound together by a mixture of saliva and liquids derived from the food itself [7]. Recent studies [27,28] or reviews [29] in young healthy subjects have shown that the particle size distribution of ready-to-swallow food boluses displays no significant intra-individual variability and only a very small inter-individual variability. This shows that a food

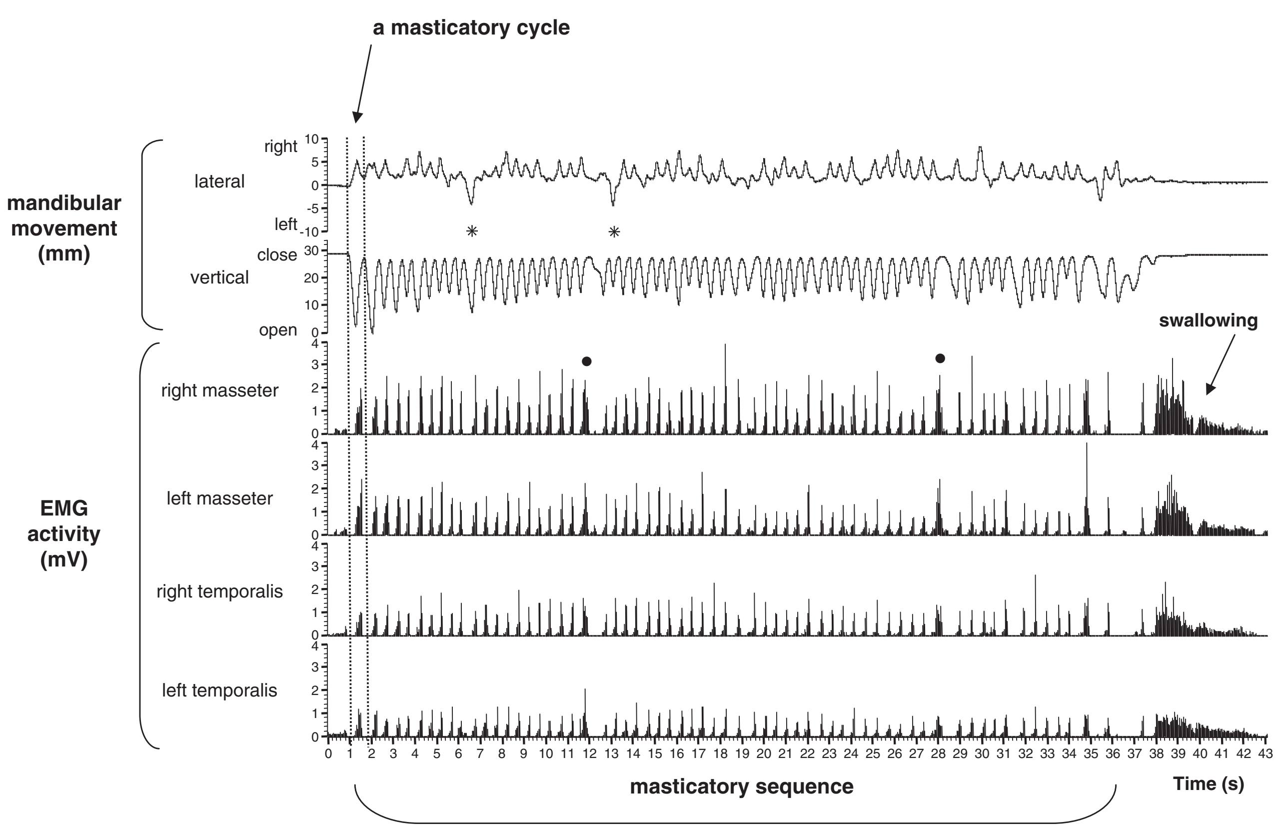

Fig. 1. Example of a complete masticatory sequence recording obtained during chewing of a plastic food product. The six traces are, top to bottom, lateral and vertical mandibular movements, electromyographic (EMG) activity of right and left masseters, and right and left temporalis muscles. Black circles (●) indicate larger EMG activity probably corresponding to intermediate swallowings. Stars (∗) mark contro-lateral mandibular deviation due to re-positioning of the food bolus.