# STUDY ON THE MASTICATION MOVEMENTS OF THE TEMPOROMANDIBULAR JOINT

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***Abstract.*** *This paper presents the results of a study on the temporomandibular joint biomechanics. The study aimed to determine the trajectories described by the mandible during the three types of movements: opening-closing, abduction-adduction and lateral movement. The results obtained can be used to determine biological mechanisms that can be used in the construction of robots, prostheses for the temporomandibular joint, etc.*

**Keywords:** temporomandibular joint,movements, trajectories

## 1. Introduction

In nature there is a wide variety of biomechanisms of prehension, which are called prehensilebiosystems. Their study has substantially contributed to the enrichment of knowledge about prehensile systems in general and has been used in the design and improvement of prehensile systems used in industrial robots and medical prostheses. Humans have two types of prehensile systems: a system represented by the handwith the five fingers and the second system of the oral cavity (the masticatory apparatus). The biomechanics of the masticatory apparatus are movements generated by the temporomandibular joint. Specialty literature offers many studies on movements allowed by the temporomandibular joint. The papers [1], [2], [3], [6] deal with aspects of the temporomandibular joint biomechanics. The biomechanical modeling of the masticatory system is a topical issue that concerns many researchers [4]. Many scientific articles in the field of dental medicine also deal with temporomandibular joint issues. The papers [6], [8] present studies of the analysis, structural and kinematic synthesis of prehensilebiomechanisms of the living world (birds, snake, human, etc.). Since 2001, there have been conducted advanced studies regarding the prehensilebiomechanics of birds, which are represented by the foot paw with the four prehensile fingers [5], [6], [8]. The number of biological models is very high and is currently being studied more and more in this field to find new models usable in different fields.

## 2. The mandible movements generated by the temporomandibular joint

The temporomandibular joint (TMJ) is the junction between the mandible and the temporal bone of the skull and is located anterior to the ear, on either side of the head. The upper round extremity of the mandible enters a cavity from the temporal bone. The joint is one of the most complex in the body, it is composed of: bones, ligaments, tendons, muscles, vessels, nerves. The temporomandibular joint is the most used joint since man uses the joint to: open and close the mouth, bite, chew, talk, yawn, etc. The temporomandibular joint makes the following three categories of movement: opening - closure of the mouth, propulsion - retropulsion of the mandible and lateral movements. Figure 1 shows a human skull and the two bones forming the temporomandibular joint are highlighted.

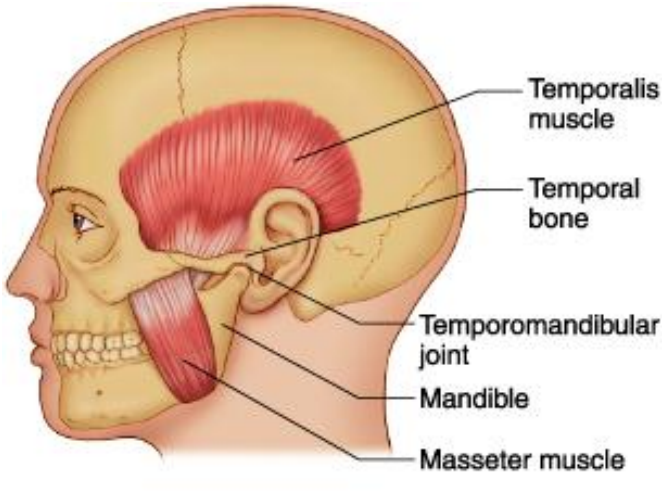


Fig. 1. The temporomandibular joint , [11]

**TMJ movements for opening-closure**

Stage I: It consists of a rotational motion of the condyle on the meniscus around a transverse axis passing through the center of the condyles and corresponding to the lower insertion of the temporomandibular ligament. The movement is 'hinge' type and the mouth opens approximately 2-4 mm;

Stage II: It consisted of two movements in TMJ: one of condilo-meniscal rotation and another of temporo-meniscal translation. The summation of the two movements (rotation, translation) causes the mouth to open with 4 centimeters.

Stage III: It is performed additionally and voluntarily. At the end of the second stage, the masseter and internal pterygoid muscles are stretched to their maximum and their fibers become parallel to the ascendant ramus of the mandible. When these muscles suddenly relax, the external pterygoid muscles contract, pulling back from the small arm of the mandibular lever and also pulling the meniscus forward. The resulting movements consist in the anterior translation of the meniscus the posterior rotation of the condyle.

**TMJ movements for propulsion - retropulsion of the mandible**

The jaw propulsion movement is achieved by translating the meniscus and the condyle. The propulsion movement is necessarily associated with a descendingmovement of the mandible. The amplitude of the mandible's descending movement depends on several factors. In the maximum propulsion the anterior slope of the condyle presses on the meniscus and on the articular tubercle. The mandibular retropulsion is achieved through the backward sliding of the meniscus and the condyle, along a horizontal or oblique plane that makes an angle of 40 ° -45 ° with the occlusal plane.

**TMJ and lateral movements**

The lateral movements of the mandible are made by sliding the condyle and the meniscus on one side and the condyle on the opposite side remains in place or slides back a little. If the interincisive line moves to the right, the condyle and the meniscus on the left side move forward, down and inward, forming an angle of 15 ° with the medio-sagittal plane. The right condyle stays in place or moves very little back and forth, and represents the vertical axis around which this lateral movement towards right side is made. Then follow the lateral movement to the left when the left condyle plays a pivotal role. The amplitude of lateral movements decreases with the opening of the mouth or with the mandibular retropulsion.

## 3. Experimental researches for the determination of the curves generated by mandibular movements

It has been proposed to study the mandible movements, respectively the trajectories described by it. For experimental research a human subject (a 53-year-old woman) was used. The subject was filmed, with two camcorders, in a 3D reference system (XOYZ). For the study of the mathematical curves generated by mandibular movements a reference point E was chosen on the incisor point. Three sequences were selected from the movie, one for each type of motion. The film decomposed in 30 images / second and the images determined the spatial coordinates of the incisor point E. The mandible is considered to be a space bar arranged in a system consisting of three reference planes: the front plan, the sagittal plane and the transverse plane. Figure 2 shows the representation of the mandible as a spatial bar in the XOYZ system. Particular points A1, B1, M1, N1, S, N2, M2, B2, A2 define the shape and dimensions of the mandible as a curved bar.

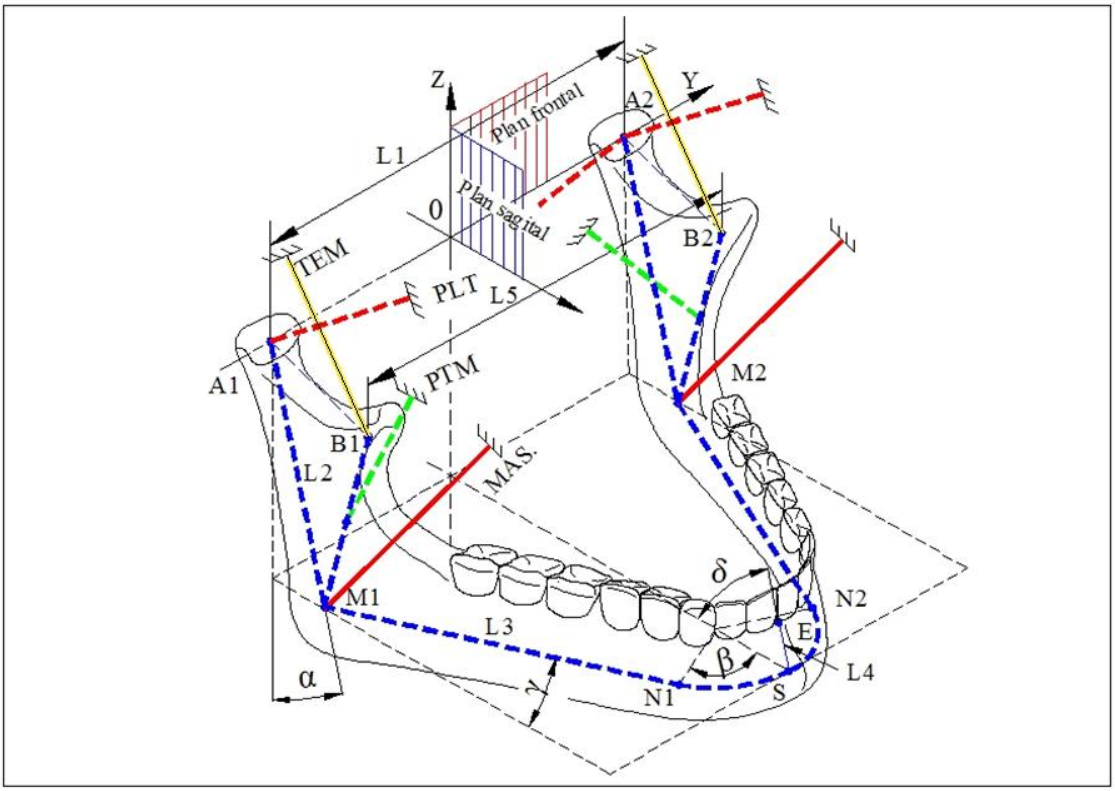


Fig. 2. The mandible as a spatial bar [1].

In Figure 2 the notations were made: TEM - temporalis muscle; MAS - masseter muscle; PTL - lateral pterygoid muscle; PTM - median pterygoid muscle. There were also noted lengths and angles in correlation with the geometric features of the mandible.

Figures 3, 4 and 5 show the results obtained for mandibular movements' trajectories. The trajectories (mathematical curves) are projected on the three reference planes.

In figure 3 it is given the projection of the curve described by point E on the sagittal plane. The curve is defined by the particular points 1-2-3-4-5-6-1. Consider the initial position corresponding to point 2. The particular points on the curve represent: 4 - maximum propulsion, 1 - maximum retropulsion, 5 - maximum opening.

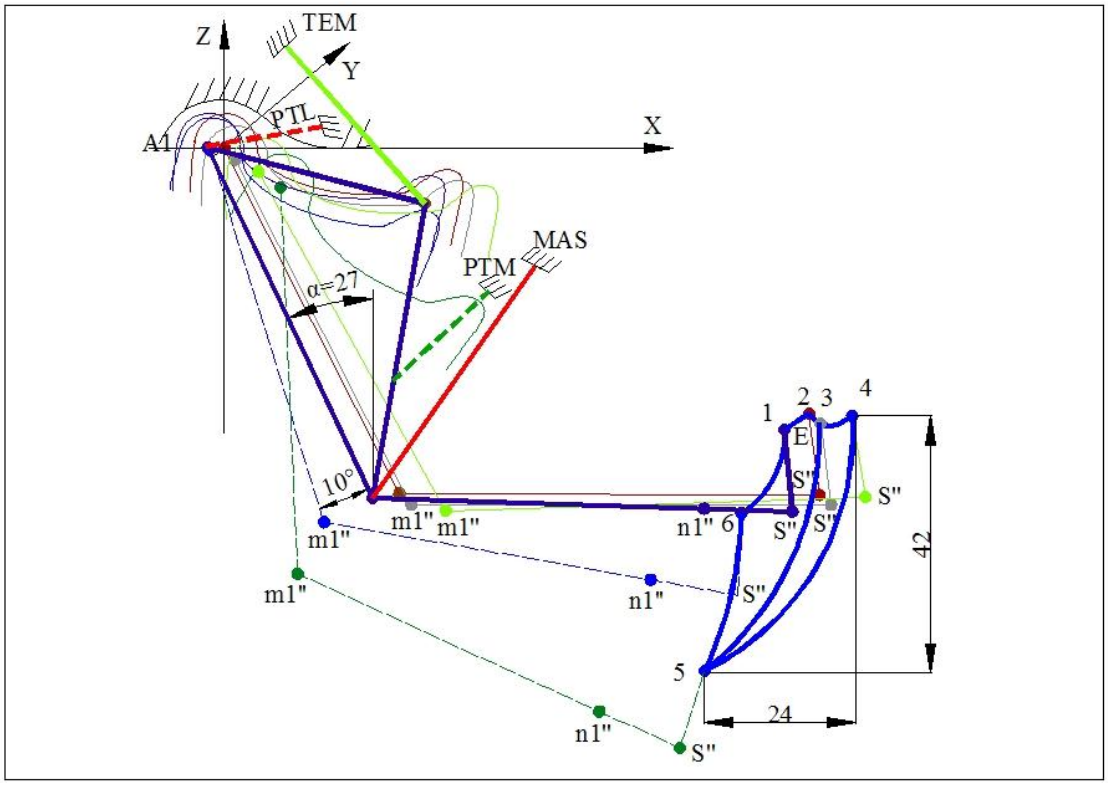


Fig. 3. The projection of the movement trajectories on the sagittal plan [1]

In figure 4 it is given the projection of the curve described by point E on the front plane. The curve is defined by the particular points 2-8-5-9-2. Consider the initial position corresponding to point 2. The particular points on the curve represent: 8 - maximum lateral to the left, 9 - maximum lateral to the right, 5 - maximum opening.

In figure 5 it is given the projection of the curve described by point E on the transverse plane. The curve is defined by the particular points 1-8-4-9-1. Consider the initial position corresponding to point 2. The particular points on the curve represent: 1- maximum retropulsion, 4 - maximum propulsion, 8 - maximum lateral to the left, 9 - maximum lateral to the right.

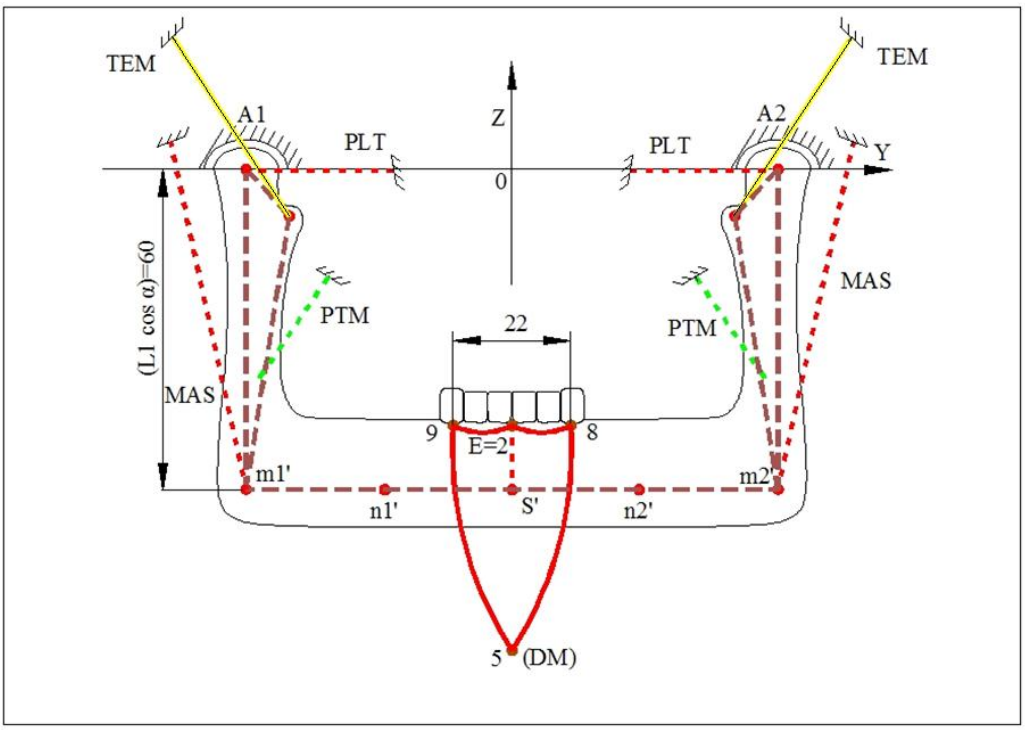


Fig. 4. The projection of the lateral movements and **opening-closure** movemnets on the front plan [1]

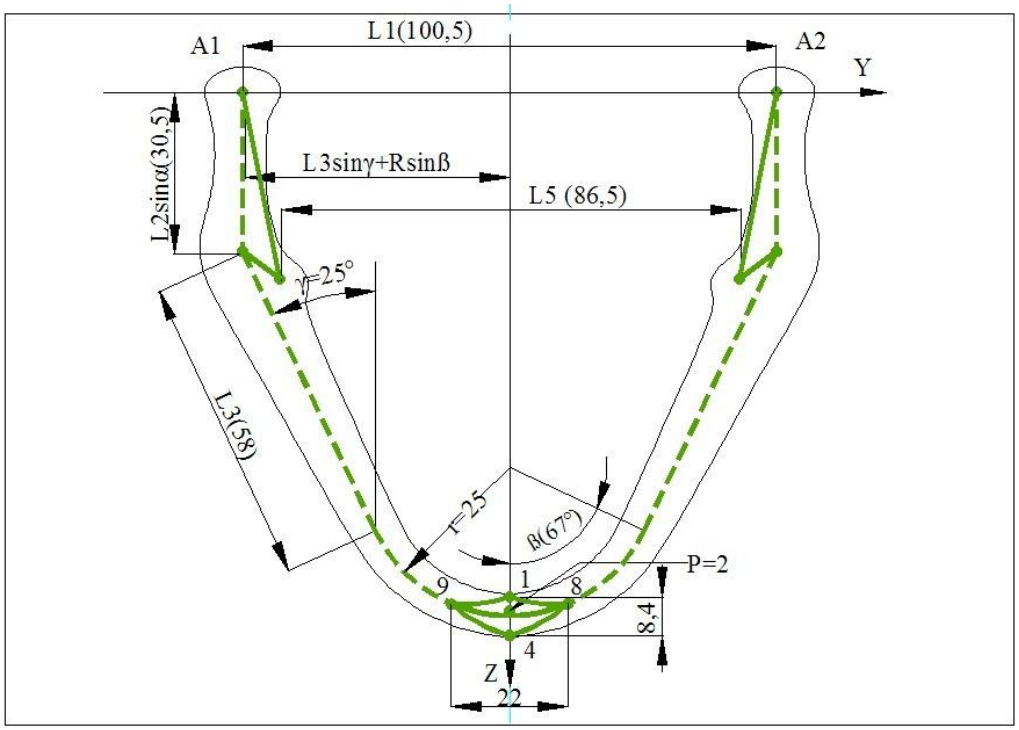


Fig. 5. The projection of the lateral movements and **propulsion - retropulsion** movement on the transverse plan [1]

## 4. Conclusions

Following the study of human mandibular movements, the curves described by the three types of mandible movements were determined. These were projected into a XOYZ reference system defined by three projection planes: the frontal plane, the sagittal plane and the transverse plane. The study of the curves described by the human mandible can be used to determine biological mechanisms. These can be used in various areas: robot construction, medical equipment industry (temporomandibular joint prostheses), toy manufacture, etc.

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