Anatomy of the Temporomandibular Joint and Masticatory Muscles in Roe Deer, *Capreolus capreolus*

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Abstract.- This study was carried out to investigate the anatomy of the structures constituting the temporomandibular joint and masticatory muscles in roe deer. Eight adult roe deer heads were used in the study. The roe deer's heads had lateromedial joint faces and an articular disc that had a thin center and thick borders that separated the joint into two free spaces. The masseter muscle, covering the lateral side of the joint, was composed of three sections; the temporal muscle covering the cranial side of the joint was composed of one section; the lateral pterygoid muscle covering the medial part was made up of two sections; and the medial pterygoid muscle, which didn't surround the joint, was also made up of two sections. It was determined that the most suitable place for intra-articular interventions in the roe deer was the caudolateral part of the joint. It was also observed that some muscle fibers of the masseter, temporal, and lateral pterygoid muscles entered and dispersed inside the articular disc, in which the elastic fibers were dense. According to the data obtained, the structure of the temporomandibular joint and the origo-insertio and the compartmentalization of the masticatory muscles were generally similar to those of other ruminants. However, the presence of the masticatory muscles entering and distributed in the articular disc was similar to those of dogs and humans.

Key Words: Articular disc, masticatory muscles, roe deer, temporomandibularis joint.

INTRODUCTION

Temporomandibular joint comprises mandibular head, mandibular fossa, articular disc, and articular capsule (Getty, 1975; Nickel *et al.,* 1986; Kabak, 2002a,b). Both the mandibular head and mandibular fossa flat structures in the ruminantia (Gillbe, 1973, 1975; Strom *et al.,* 1995; Kabak, 2002a; Herring, 2003). The articular disc, which is a fibrocartilaginous or fibrous structure, allows for smooth movement between the articular surfaces of the temporomandibular joint, which move as an incongruent ginglymus (Gillbe, 1973; Nickel *et al.,* 1986; Fenol *et al.,* 1992; McKay et *al.,* 1992; Kabak, 2002a, b; Schumacher, 2006). This structure has been examined macroscopically (Gillbe, 1973; Nickel *et al.,* 1986; Strom *et al.,* 1995) and microscopically (Gillbe, 1973, 1975; Fenol *et al*., 1992; Strom *et al*., 1996). In bovines, the center of the articular disc in particular becomes

harder with age, and the temporomandibular joint becomes more vulnerable to secondary damage such as fracture and tissue injury or degradation (Tanaka *et al.,* 2006). There are three different masticatory movements—rotation (opening-closing), slipping (forward-backward), and lateral (sideways)—and all of these are observed in the temporomandibular joint (McKay *et al*., 1992; Arıncı, 1997). In humans and ruminants, the lateral movement is well developed (Nickel *et al.,* 1986; Fenol *et al.,* 1992). The masseter, temporal, medial, and lateral pterygoid muscles are masticatory muscles in mammalians and play a major role in chewing food (Nickel *et al*., 1986; Velesco *et al*., 1993; Schmolke, 1994).

There are studies exploring the relationship between the method of chewing, the structural differences in the masticatory muscles, and the components that form the temporomandibular joint (Gillbe, 1975; Demirsoy, 1992; Bermejo *et al*., 1993; Kalpakci *et al.,* 2011). Also, the temporomandibular joint has recently been investigated by ultrasonography and magnetic resonance imaging (Rodriguez *et al*., 2007; Macready *et al.,* 2010). However, as far as we

know, no studies of this nature have been carried out so far in roe deer. This article was written to determine the possible similarities or differences related to the temporomandibularis joint and masticatory muscles between other domestic ruminants and the deer.

MATERIALS AND METHODS

This study was performed with the permission of the General Directorate of Nature Conservation and National Parks of the Ministry of Forestry and Water Affairs of Turkey. In this study, a total of 16 temporomandibular joints belonging to eight adult roe deer (*Capreolus capreolus*), weighing between 18–25 kg, were used. In order to examine the bony components of the temporomandibular joint, three roe deer heads were macerated with 5% NaOH (Luna, 1968). Five roe deer heads were fixed in a 10% formalin solution, and the macroanatomic findings from the masticatory muscles and joints were taken. The fiber courses of the masticatory muscles, the articular disc, and the dissection of the temporomandibular joint were examined by an Olympus SZ61 TRC stereomicroscope, and the dimensions of the discs were measured by caliper compass (Mitutoyo, Tokyo, Japan). The photographs were taken using a C-5060 digital camera. For the histological examination, the temporomandibular joints of the two roe deer heads were decalcified using the formic acid-Na citrate method (Luna, 1968), and a total of four articular discs dissected from the heads were embedded in paraffin wax. Then they were sectioned to a thickness of 5–6 µm horizontally for the disc and sagittally for the joint. The Crossman's modified triple staining method (Crossman, 1937) was applied to determine the general structure of the decalcified joint and disc. In order to analyze the elastic fibers, the Weigert elastic staining method (Luna, 1968) was used. Gomori's one-step trichrome staining method (Luna, 1968) was used in order to clearly reveal the course of the muscle fibers in the articular disc. The existence of desmin was observed using the immunohistochemical streptavidin-biotin-complex method (True, 1990). For immunohistochemical stainings, primary antibodies of rabbit polyclonal desmin (DES)

(ABIN736566) were used. Histostain Plus Rabbit Primary System (Zymed kit: 85-6743) was used for the detection of secondary antibodies. The sections were subject to a deparaffination process and were permeabilized in a citrate buffer solution by microwaving at 700 watt power for proteolysis. They were then washed in a phosphate buffer solution (PBS), and endogenous peroxidase activities were blocked with 3% H_2O_2 for 10 min at room temperature. After washing with PBS, the sections were blocked with rabbit serum for 30 min, followed by incubation with primary antibodies against the desmin antigen (1:200), at 4°C overnight. After washing with PBS, the sections were incubated in biotinylated secondary antibody for 30 min at 37°C. Then the sections were washed in PBS and were incubated in streptavidin-HRP complex. Antibody binding was detected with a 3,3'-diaminobenzidine kit, and the sections were counterstained with hematoxylin. The immuno-histochemical staining method was applied in order to reveal the localizations of muscle cells and desmin filaments in accordance with Gomori's technique. A Nikon E–600 research microscope was used for the histological examinations and photographs.

RESULTS

The temporomandibular joint was above the occlusal plane in the roe deer (Fig. 1A). The mandibular head (Fig. 1a) and mandibular fossa (Fig. 1b), which consist of the temporomandibular joints, were positioned in a lateromedial direction (Fig. 1B). It was observed that the caudal part of the joints was covered with a thin joint capsule and was supported by fat and connective tissue, while the other parts of the joints were surrounded by masticatory muscles. The lateral, craniomedial, and medial parts of the joints covered the profound leaf of the masseter muscle (Fig. 1c and c'), the temporal muscle (Fig. 1d), and the dorsal part of the lateral pterygoid muscle (Fig. 1e), respectively. For this reason, it was understood that intra-articular implementation must be carried out from the caudal side. But due to the bony prominence (postglenoid process) (Fig. 1 arrow) which was in the vertical direction in the caudomedial part of the joints, the
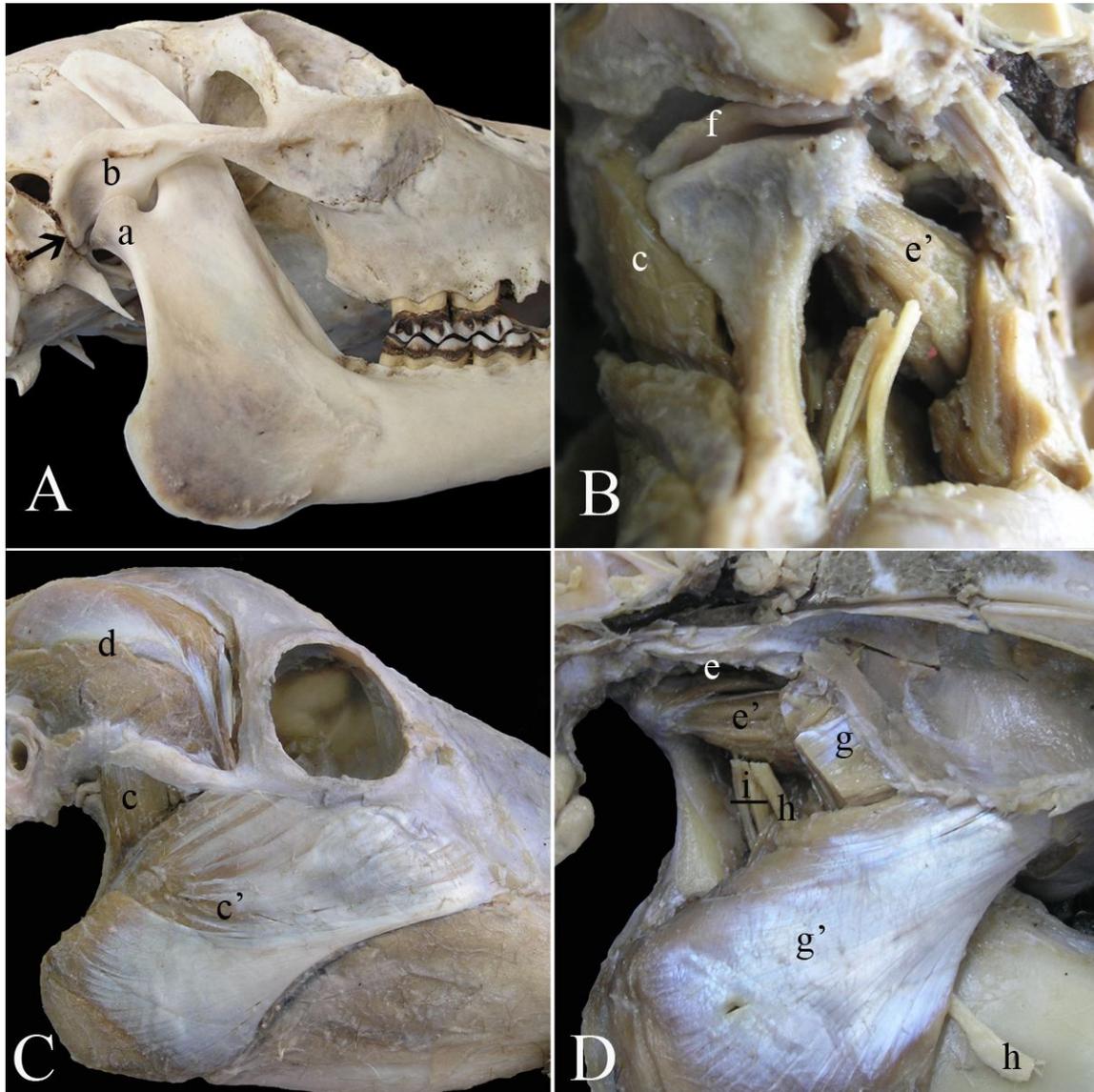
Fig. 1. The macroanatomic view the bone structures constituting the temporomandibular joint (A), articular disc and muscles surrounding the temporomandibular joint (B), lateral view (C) and medial view (D) of masticatory muscles in roe deer.

a, condylar head; b, temporal fossa; c, the profund part of the masseter muscle; c', the superficial part of the masseter muscle; d, the temporal muscle; e, the dorsal part of the lateral pterygoid muscle; e', the ventral part of the lateral pterygoid muscle; f, articular disc; g, the lateral part of the medial pterygoid muscle; g', the medial part of the medial pterygoid muscle; h, lingual nevre; i, alveolar mandibular nerve arteria and venae; arrow, glenoid process.

caudolateral area was determined to be the most appropriate place for this.

The lateromedial length of the articular disc (Figs. 1f, 2 A,B), which was thick at the borders and thin at the center, was measured to be 16.83±1.4 mm on the right and 16.95 ± 1.8 mm on the left. Its rostrocaudal length was 10.28 ± 0.4 mm on the right and 10.04±0.5 mm on the left. It was observed that the articular disc separating the articular cavity into two independent spaces was connected to the joint capsule (Fig. 2A) and was a fibrocartilaginous structure (Fig. 2C). It was determined that the
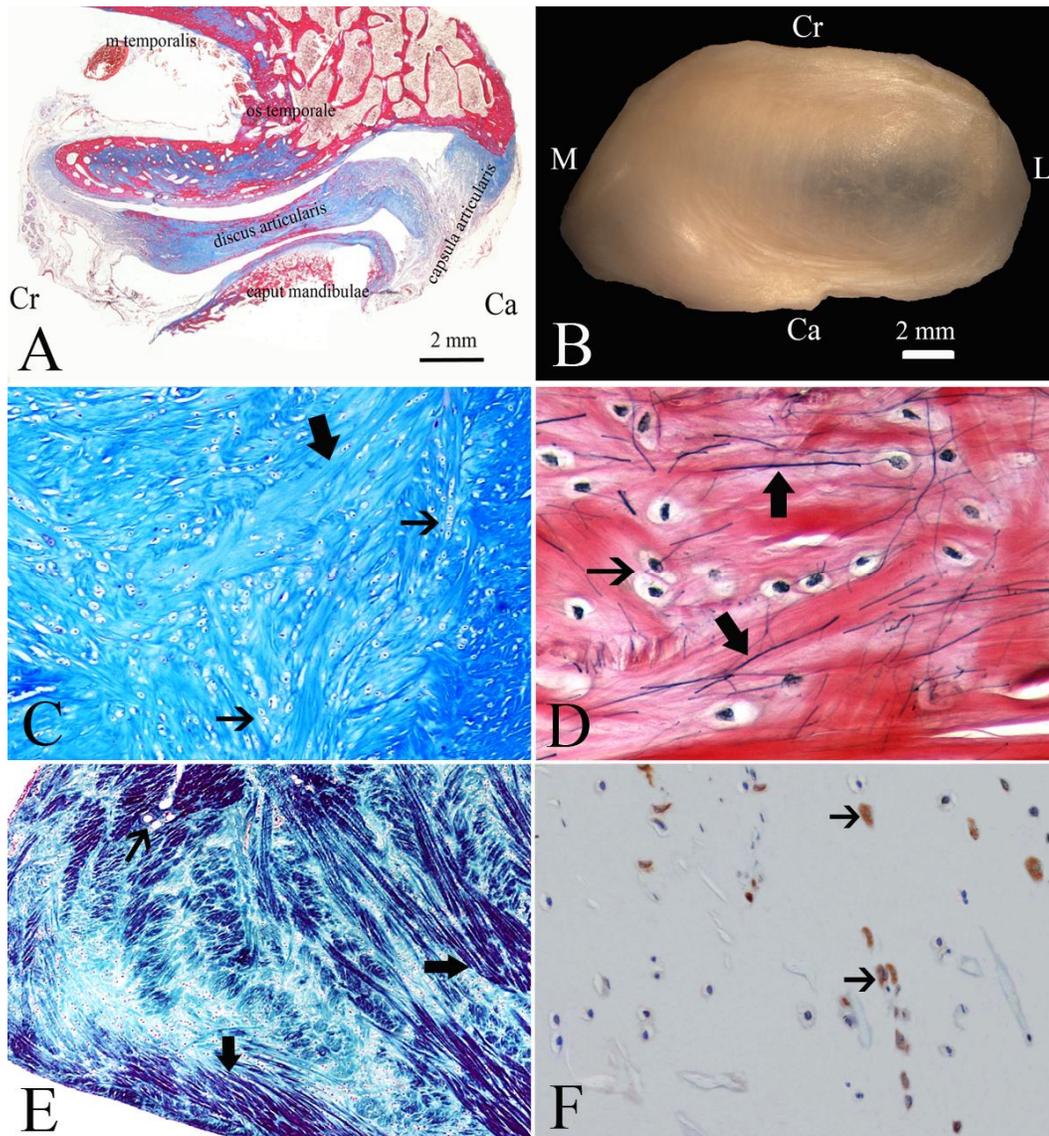
Fig. 2. The subgross view of the temporomandibular joint (A) and articular disc (B), and the histological view of articular disc (C, D, E, F) in roe deer.

C and D, thin arrows; cartilage cells shape binary or isogene groups; C, thick arrow; collagen bundles; D, thick arrow; elastic fibres; E, thin arrow; capillary vascular sinusoid form; E, thick arrow; F, arrow; muscle fibres distributed inside the articular disc.

cartilage cells were lined up in binary or triple isogene groups, and the collagen bundles (Fig. 2C thick arrow) generally lay on a lateromedial course in the articular disc. At the central parts of the disc, many elastic fibers (Fig. 1D thick arrow) were found. In the rostral part of the articular disc, it was determined that the vascular capillaries were in a sinusoid form (Fig. 2E thin arrow). Interestingly, it was observed that the muscle fibers belonging to the dorsal part of the lateral pterygoid muscle from the caudomedial part of joint, and the muscle fibers belonging to masseter and temporal muscles from the cranial part of joint, were all distributed inside the articular disc (Fig. 2E thick arrow and 2F arrow).

Four masticatory muscles were examined: the

masseter (Fig. 1C), temporal (Fig. 1C), medial (Fig. 1D), and lateral pterygoid (Fig. 1A, D) muscles.

Masseter muscle

The masseter muscle was divided into three separate parts: superficial (Fig. 1c'), intermediate, and profound (Fig. 1c). The superficial part of the masseter muscle, originating from the facial tuber of the maxilla and the facial crest of the zygomatic bone, was inserted into the angle of the mandible and the lateral surface of the ramus of the mandible. The muscle fibers of this part were coursed caudoventrally. It was observed that the intermediate part, which originated from the ventrolateral surface of the zygomatic bone, ended at the caudal and ventral borders of the ramus of the mandible. Its fibers were headed in a ventral direction. The rostroventral muscle fibers of the profound part, originating from the zygomatic arch, were connected to the rostral border of the ramus of the mandible. The lateral part of the joint was completely covered with the profound part of the masseter muscle.

Temporal muscle

The temporal muscle (Fig 1d) originating from the temporal fossa was a poor muscle, according to the masseter muscle, and surrounded the coronoid process laterally and medially. The muscle fibers laterally surrounding the coronoid process were inserted at the rostral and lateral edges of the ramus of the mandible, while the muscle fibers medially surrounding the coronoid process ended at the ventral part of the mandibular foramen situated in the medial side of the ramus of the mandible.

Lateral pterygoid muscle

It was observed that the lateral pterygoid muscle had a dorsal (Fig. 1e) and a ventral part (Fig. 1e'). The dorsal part was small. It started at the wing and pterygoid process of the basisphenoid bone and connected to the joint capsule on the tip of the medial side of the mandibular condyle. The ventral part originating from the lateral surface of the pterygoid bone and inserted into the pterygoid fovea and onto the rostromedial border of the mandibular condyle was comparatively bigger. The muscle

fibers of the two parts were oriented in a sagittal direction.

Medial pterygoid muscle

It was observed that the medial pterygoid muscle had a lateral (Fig. 1g) and a medial part (Fig. 1g'). The lateral part started at the lateral side of the perpendicular part of the palatine bone and the pterygoid bone, and it ended in the pterygoid fossa, which was on the medial surface of the ramus of the mandible. It was observed that the medial part originated from the hamulus of the pterygoid bone and from the margo liber of the palatine bone and terminated in the angle of the mandible. The muscle fibers of both parts were headed in a caudoventral direction.

DISCUSSION

The observations in this study, the temporomandibular joint being above the occlusal plane, the direction of the bony components forming the joint, the structure of the joint capsule, and the anatomic components surrounding the joint capsule, were in agreement with those in other previous studies (Gillbe, 1975; Fenol *et al.,* 1992; Bifano *et al.,* 1994; Schmolke, 1994; Strom *et al.,* 1995; Kabak, 2002a). The distinct and vertically extended postglenoid process running from the caudomedial part of the joint observed in this study was consistent with the findings of Strom *et al.* (1995) in the Swedish moose. Hence, the most appropriate place for the intra-articular application was the caudolateral part of the joint in the roe deer, because of the position of the postglenoid process.

There are three different masticatory movements in domestic mammals that have different dietary specializations such as carnivores, herbivores, and rodents. These movements have altered with respect to the anatomic structures contributing to the temporomandibular joint and masticatory muscles that were well developed (Scapino 1965; Getty, 1975; Weijs, 1975; Nickel *et al.*, 1986). It has been stated that the joint movements of the carnivore occur mostly in the form of opening and closing (rotational) movement (Scapino, 1965), in herbivores, sideways (lateral) movement (Getty, 1975; Nickel *et al.,* 1986), and in

rodents, mostly forward-backward (slipping) movement (Weijs, 1975). Being herbivorous, the roe deer's mandibular head was concave and the mandibular fossa was lateromedial in direction, and also, the medial and lateral pterygoid muscles were well developed. Therefore, the temporomandibular joint of the roe deer permits more lateral movement. This situation is similar to that in other ruminants that are herbivorous.

The thick borders and thin center of the articular disc and its connection to the joint capsule were similar to what has been described in the literature (Nickel *et al.,* 1986; Fenol *et al.,* 1992; Kabak, 2002a). However, one study has indicated that the disc is connected to the mandibular head on the lateral side and to the temporal bone on the medial side in sheep, and another study (Rodriguez *et al.,* 2006) has also shown that the disc is connected to both the joint capsule and the mandibular head and the temporal bone in horses. In a comparative study about the measurements and structure of the articular disc, carried out using different species, it has been stated that humans' discs are most similar to those of pigs (Kalpakci *et al.*, 2011). The length (approximately 1 cm) of the rostrocaudal part of the articular disc of the roe deer was consistent with the findings of Kalpakci *et al.* (2011) with respect to goats. The fibrocartilaginous structure of the articular disc, the course of the movements of the collagen bunches, and the distributions of the elastic fibers were similar to those in the literature (Gillbe, 1973, 1975; Kabak, 2002a). There are different expressions regarding the orientation of sinusoid type blood vessels in the articular disc. It has been reported that the sinusoid type blood vessels are present in all parts of the disc in Akkaraman sheep (Kabak, 2002a), in the caudal part of the disc in goat (Bifano *et al.,* 1994), and in the center of the disc in Scandinavian moose (Storm *et al.,* 1996). In this study, the blood vessels being in the rostral part of the disc and the orientation of these vessels were similar to those seen in sheep (Gillbe, 1973; Bosanquet and Goss, 1987).

The most important finding in this study was that the muscle fibers reached the inside of the articular disc. Specifically, it was determined that the dorsal part of the lateral pterygoid muscle entered the disc from the caudomedial side, whereas the temporal muscle and the profound leaf of the masseter muscle penetrated the disc from the rostral side. Staining was carried out according to the Streptavidin-Biotin-Peroxidase method (True, 1990) to analyze the desmin filaments, and it was determined that the muscle fibers were concentrated at the periphery of the disc, whereas at the center of the disc, they were present only around the cores. Although it has been stated that some muscle fibers of the lateral pterygoid muscle in the dog (Tomo *et al.,* 1995) and of the other masticatory muscles except the medial pterygoid muscle in the horse (Rodriguez *et al.,* 2006) and human (Bade *et al.,* 1994) reached to the articular disc, according to our knowledge, there are no studies regarding whether or not muscle fibers exist in the articular discs of any ruminants. The presence of these muscle fibers in the articular disc of the roe deer has been examined for the first time in this study.

The muscle fibers in the disc could be responsible for the forward movement of the disc when these muscles are contracted as well as the disc's proper positioning during mastication.

Although the digastric muscle has been specified as one of the masticatory muscles by some researchers (Scapino, 1965; Getty, 1975), in this study, the masticatory muscles have been observed as the masseter, temporal, lateral, and medial pterygoid muscles, similar to what is the case in the literature (Schmolke 1994; Velesco *et al.,* 1993). The origin and insertions of the masticatory muscles and their segmentation were generally similar to what is described in the literature (Gillbe 1973, 1975; Velesco *et al.,* 1993; Schmolke, 1994; Kabak, 2002a,b). The results of Getty (1975), who examined the temporal muscle as one part, and those of Kabak (2002a), who examined the medial pterygoid muscle in two parts, were similar to the results of this study. Moreover, examination of the dorsal and ventral parts of the lateral pterygoid muscle was compatible with other previous studies (Carpentier *et al.,* 1988; Strom *et al.,* 1988; Schmolke, 1994; Kabak, 2002a). And as in humans (Carpentier *et al.*, 1988; Schmolke, 1994) and in dogs (Strom *et al.,* 1988), some fibers in the dorsal part of the muscle have been observed to be present in the articular disc. As a result, the structures of the temporomandibular joint and the masticatory

muscles were observed in the roe deer. The structure of the roe deer's jaw joint and the components that comprise this joint are generally similar to those of other ruminants, though the entrance and dispersal of the muscle fibers in the articular disc have been examined for the first time in this study. The findings are similar to those available for humans and dogs.

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