Acta of Bioengineering and Biomechanics
Vol. 5, No. 2, 2003

Equine masticatory organ. Part II. Parodontium

S. ŁYCZEWSKA-MAZURKIEWICZ, J. KURYSZKO,
A. PRZETOCKA-WYDRO, P. KUROPKA

Department of Histology and Embriology,
Faculty of Veterinary Medicine, Agriculture University of Wrocław,
Kożuchowska 5, 51-631 Wrocław, Poland

This paper is the second part of the study devoted to the equine masticatory organ. The masticatory organ is a morphological-functional unit associated primarily with the digestive system. It includes the teeth (described in part I); parodontium (described in the present paper); oral mucosa, maxilla and mandible as well as some of the viscerocranial bones (the temporal and zygomatic bones), temporo-mandibular joints, muscles and oral glands.

The parodontium as a part of the masticatory organ can be divided into the marginal parodontium and the apical parodontium. The marginal parodontium (*parodontium marginale*) involves the adjoining tissues in the region of the body of a tooth: the gingivae, periodontium, periosteum and the alveolar bones. The apical parodontium (*parodontium apicale*) also includes the radical cementum, despite the fact that it builds a tooth.

Key words: teeth, alveolar bone, molar teeth, cementum, temporomandibular joint, bone mineral dentistry

1. Cement (*cementum*)

There are two kinds of cementum, i.e. cellular and acellular, which differ in morphology; however, depending on cementum distribution within the tooth, we deal with central, macrocavernous cementum (which fills the infundibula) and the marginal, microcavernous cementum covering the outside of a tooth.

The cementum is produced by cementoblasts. The process takes place in response to eruption, inflammatory conditions, trauma and damage. The cementum covers the whole external surface of a tooth, preceding its eruption and it also fills the infundibula of the maxillary teeth. In its chemical composition, the cementum resembles the dentine: it consists in 65% of inorganic and in 35% of organic substances and water (the texture of cementum is made up of the matrix, calcified collagen fibres, glycoproteins and mucopolysaccharides).

Topographically, the cementum is divided into:

- supragingival cementum, which fills the irregularities in the tooth surface, protects the enamel and is non-vascularized,
- subgingival cementum, which is a part of the periodontal ligament complex (vascularized).

The layer of cementum on the borderline with the dentine consists of acellular elements and constitutes a thin structure surrounding the root and limiting the enamel. The acellular cementum is a thin layer arising from the amelocemental junction which thickens upon approaching the apex of the root [2], [9], [12], [19].

The second, thicker layer of cementum is composed of cementocytes situated in the cemental lacunae. It is a cellular cementum which is deposited on the surface of the acellular layer. In some cases, the cellular cementum may be situated directly on the dentine. Cementocytes have numerous, long, radially arranged processes which communicate with neighbouring cells. The processes of marginally situated cells project towards the periodontal. The cementocytes processes are the longer and the more densely arranged, the closer they are to the dentine [17].

The outermost, third layer consists of unshaped precementum. The cementum is not resorbed in physiological conditions, thus on aging certain segments of cementoblasts form new layers and replenish the cementum loss resulting from resorption.

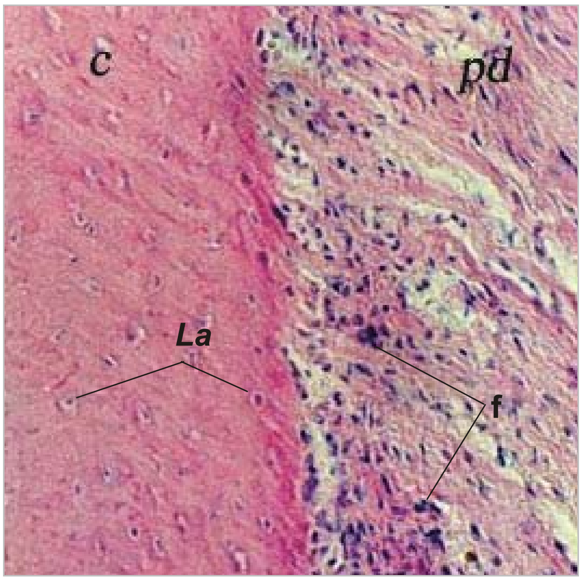

Fig. 1. Light micrograph of the periphery of a decalcified equine cheek tooth showing the periodontal ligament (pd) containing fibroblasts (f). The adjacent peripheral cement (c) contains lacunae (la) of the cementoblasts (hematoxylin-eosin, magnification × 200)

The layer of cementoblasts is continued as an interrupted bundle of thick collagen fibres forming the periodontal ligament – the major ligament fixing the tooth in the tooth socket (the gingival depression of the bone). The arrangement of collagen fibres running among the cementoblasts and crossing the cementum layer enables firm anchoring of the tooth in the tooth socket. Continuous deposition of the cementum in the region of the apical foramen of the root canal consequently leads to its progressing narrowing. In 10-year-old animals, the apical foramen becomes eventually totally obliterated. Such an obliteration is beneficial for the periapical tissues as it eliminates the possibility of a pathogenic effect of stimuli from the root canal [1].

In this way, the thickness of cementum increases with age, but this has no effect on better keeping of the tooth in the tooth socket, as the periodontal fibres are attached only to the external, newly formed layers of cementum (figure 1).

2. Periodontium

The collagen fibres of the periodontium form thick bundles which are interwoven with blood and lymph vessels and nerves. The bundles enter the cementum from the side of the root, being limited from the other side by the alveolar bone into which they penetrate in the form of calcified fibres. The collagen fibres of the periodontium are made of the collagen of type I and they form interweaving bundles. They run in waves from the cementum to the alveolar bone, which enables their elongation and shortening. Fibres arising from the alveolar bone join those running from the cementum and in the mid-thickness of the periodontium they form the so-called intermediary plexus. It enables lateral movements of the teeth under the effect of forces of mastication and protects the tooth against the forces of mastication.

The periodontal ligament (*lig. periodonticum*), in comparison with other ligaments, contains a large number of cells, vessels and is a metabolically active structure; this makes the tooth more mobile and vital and increases its resistance to the pathogens entering the oral cavity [5], [8], [13].

The periodontal fibres are divided into three groups, depending on their location and course:

1. Those which secure the tooth in the socket and condition its physiological mobility.
2. Those which stabilize the alveolar bone and are responsible for physiological renewal of the alveolar bone.
3. Integrating fibres.

The fibres running towards the cementum and the alveolar bone are more stable which decreases the rotation power and the acting forces [6], [18], [19], [23]. In contrast to them, the intermediate part, which is the main part of the ligament, is made up of young collagen fibres with smaller diameter. Such fibres intersect and form a thickly woven texture which is attached to the peripheral rather than to the stable layer of the ligament. The layer of integrating fibres contains a significant amount of fibroblasts which produce collagen and glycosaminoglycans.

The formation of new fibres and degeneration of old ones are brought about by the same population of cells (fibroblasts) that are responsible for mobility (rotation mechanism).

Within the periapical foramen the periodontium joins with the pulp, forming a ligament system consisting of:

1. Alveolo-dental ligaments (*lig. alveolare*).
2. Circular ligaments (*lig. circulare*).
3. Interalveolar ligaments (*lig. interalveolare*).

The alveolo-dental ligament consists of four bundles of fibres which differ in the aligment and attachment site: the uppermost bundle of the crest of the alveolar process, the horizontal bundle, the oblique bundle and the vertical bundle which secure the root in the tooth socket. This differentiated arrangement of the fibres counteracts the masticatory forces acting from various directions. The periodontium is richly innervated, it contains numerous endings of sensory nerves. The sensory, pain, touch receptors distributed alongside the cementum and the alveolar wall by the trigeminal nerve control involuntarily the process of mastication. Every pressure exerted on the tooth is transmitted by the periodontium to the sensory nerve endings which determine direction, degree and intensity of the pressure. On biting and chewing of hard food particles, irritated sensory endings regulate the tone of the masticatory muscles, decreasing their activity – in this way the periodontium protects the tooth against excessive overload and prevents its forcing into the tooth socket [1], [13].

3. Periosteum and the alveolar process bone (*osseus processus alveolaris*)

The teeth are embedded in the horse-shoe-shaped denture edges in the mandible and in the maxilla, which are referred to as the dental arches. Every dental arch consists of the right and the left alveolar processes, which contain the following layers:

- periosteum in the form of a thin layer shaping the alveolar wall,
- the cortical layer – a dense, compact structure which forms the external part of the tooth socket, consisting of two external laminae durae and a layer of spongy bone between them,
- the spongy layer – a layer of spongy bone inside the dense cortical layer of the bone.

Spongy bone contains spaces filled with bone marrow. It undergoes constant restructuring. Numerous thick and fine, irregularly spaced interdental and interradical trabeculae and large marrow cavities are visible in X-ray picture (figure 2). External laminae of the alveolar bone are covered with the periosteum which is composed of fibrous plexiform tissue. It is attached to the bones by means of collagen fibres [4], [14], [18].

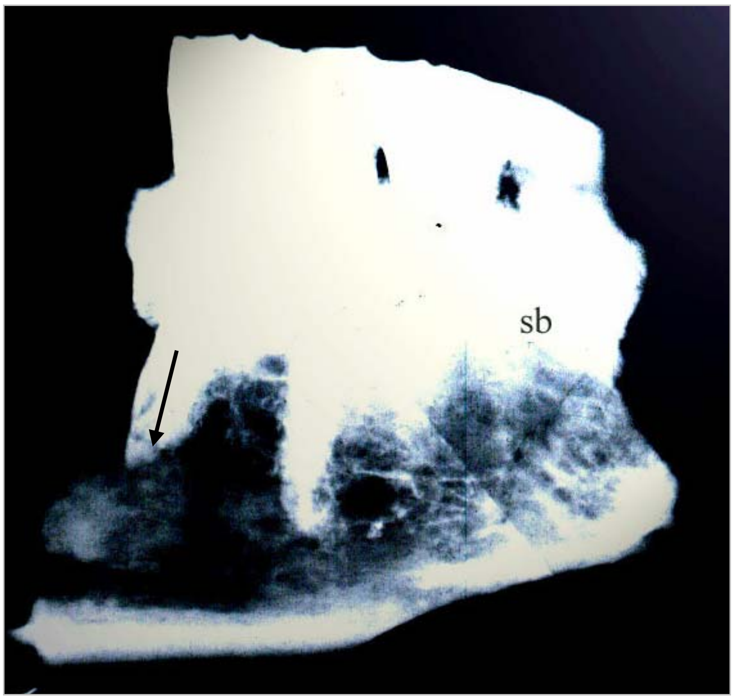

Fig. 2. Lateral radiograph of the left mandibulary arcade-layer of spongy bone (sb) inside the dense cortical layer of the bone (mAs 125 □ 0.15)

The bone is separated from the periosteum by a layer of osteoblasts which participate in the constant restructuring of the bone. On the edges of the upper interalveolar septa the periosteum joins with the periodontium which lines the tooth socket. The periosteum adheres most closely to the bone in the sites of attachment of tendons and ligaments. The periosteum is well innervated, therefore all inflammatory conditions manifest themselves as severe pain. The lamina dura of the alveolus in its external part lining the tooth socket is composed of bone with thick, long collagen fibres which make the periosteal ligament system. The fibre bundles perforate the intercellular substance of the cementum, where in the course of progressing mineralization they become immured (*fibre perforantes cementii*) forming plexuses (plexiform bone) (figure 3). The internal portion of the lamina dura is composed of bone trabeculae.

In the walls of the cortical layer of the tooth socket, there are numerous openings, forming the so-called alveolar sieve through which the lymph and blood vessels pass to the periodontium, and in the case of pathological processes taking place in the periapical tissues this structure allows a free passage of the exudates into the spongy bone [18], [21].

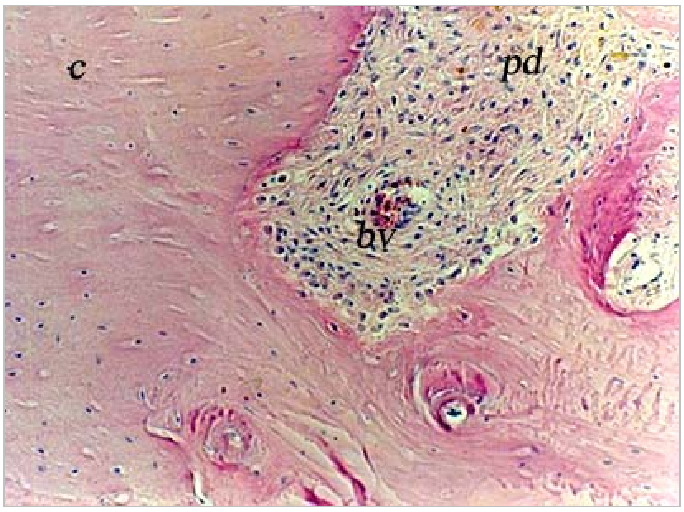

Fig. 3. Light micrograph of equine molar tooth showing fibres of the periodontal ligament (pd) run to the cementum (c) and insert as (fibre perforantes cementii), blood vessel (bv) (hematoxylin-eosin, magnification × 200)

The alveolar bone fulfills the following functions: reconstruction of the bone tissue and fixation of the periodontal fibres as well as restoration of bone loss resulting from pathological resorption. The process of alveolar bone reconstruction is stimulated by mastication forces. Physiological tooth movements cause ongoing reconstruction of the bone. Elimination of the tooth from occlusion results in depletion of the alveolar bone and weakening of the ligament system. The bone, which has lost its adaptability to the effect of mechanical forces, is eliminated by osteoclasts, and osteoblasts form new bone tissue.

The bone, being one of the hardest tissues, is extremely flexible. The physiological movements of a tooth exert pressure which is carried onto the alveolar wall by the periodontium.

The fibres of the periosteum are attached to the spongy bone. When the spongy bone reaches certain thickness, limited foci of resorption appear with temporary weakening of fibrous attachment. However, the resorption does not occur in the whole alveolar wall at the same time, hence not all the fibrous attachments are weakened simultaneously. Under physiological conditions the processes of bone resorption and formation are in balance. In the course of inflammatory processes, the balance is disturbed and the osteoclasts activity prevails.

4. Gingiva

The gingivae are the extensions of the oral mucous membrane which cover the alveolar processes of the maxillary and the mandibular bones. The gingivae adhere tightly to the teeth on the border of the body and the root of a tooth. They join with the alveolar periosteum thanks to connective tissue fibres. The gingivae are poorly innervated but have an abundant vascular supply [23].

The development of the parodontium is connected with the eruption of teeth since at the same time a junction between the tooth and the gingiva is formed in 1/3 of the tooth body as the epithelial attachment of the gingiva. This is the site in which the external, comentum-covered surface of the tooth joins the gingival epithelium.

The epithelial attachment of the gingiva plays a significant role in the physiologhy and pathology of the parodontium. It makes the bottom of the gingival groove (physiological gingival pocket), i.e. the gingival crevice between the cementum and the internal gingival epithelium.

The internal epithelium of the pocket and the epithelium of the attachment, contrary to the epithelium of the external surface of the gingiva, do not undergo cornification, so they may easily undergo mechanical, toxic and bacterial trauma. In the horse, the process of shortening of the buccal teeth starts from the age of 8 years. As the occlusal surface undergoes attrition and the body becomes shortened, the tooth starts to move upward from the tooth socket in order to replace the loss. Also the epithelial attachment moves up and this may be followed by atrophy of the alveolar processes and lowering of the gingivae. This process is called "passive eruption" [3], [7], [8], [19], [22].

The dental organ in the horse is designed to crash hard grain and to shred plants rich in cellulose, which requires a sufficient force, much greater compared to carnivorous animals. The structures supporting the masticatory organ (muscles, glands, joints and their mutual relations) as well as the mechanism of mastication will be discussed in part III.

References

[1] BARAŃSKA M., *Choroby tkanek okołowierzchołkowych*, 1985, 13–40.
[2] BOYDE A., *Equine dental tissues: a trilogy of enamel, dentine and cementum*, Equine Vet. J., 1997, May 29, 198–205.
[3] BUTLER, *Dentition in function* [in:] *Dental Anatomy and Embryology*, Blackwell Scientific Publications, 1991, 345.
[4] DIXON P.M., COPELAND A.N., *The radiological appearance of mandibular cheek teeth in ponies of different ages*, Equine Veterinary Education, 1993, 5, 317–323.
[5] FORTELIUS M., *Ungulate cheek teeth: developmental, functional and evolutionary interrelations*, Acta Zoologica Fennica, 1985, 1–76.
[6] FAWCETT D.W., *A Texbook of Histology*, W.B. Saunders, Philadelphia, 1987, 603–618.
[7] GORREL C., *Equine dentistry: evolution and structure*, Equine Vet. J., 1997, May 29, 169–70.
[8] BAKER G.J., EASLEY J., *Equine Dentistry*, 2002, 5–30, 259–231.
[9] KILIC S., DIXON P.M., KEMPSON S.A., *A light microscopic and ultrastructural examination of calcified dental tissues of horses*: 1. *The occlusal surface and enamel thickness*, Equine Vet. J., 29, 191–197.
[10] KILIC S., DIXON P.M., KEMPSON S.A., *A light microscopic and ultrastructural examination of calcified dental tissues of horses*: 3. *Dentine*, Equine Vet. J., 1997, 206–212.
[11] KILIC S., DIXON P.M., KEMPSON S.A., *A light microscopic and ultrastructural examination of calcified dental tissues of horses*: 2. *Ultrastructural enamel findings*, Equine Vet. J., 1997, May 29, 198–205.

[12] KILIC S., DIXON P.M., KEMPSON S.A., *A light microscopic and ultrastructural examination of calcified dental tissues of horses*: 4. *Cement and the amelocemental junction*, Equine Vet. J., 1997, May 29, 213–219.
[13] KILIC S., *A light and electron microscopic study of the calcified dental tissue in normal horses*, Thesis, University of Edinburgh, 1995.
[14] KIRKLAND K.D., BAKER G.J., MARRETTA S.M., LOSONSKY J.M., *Effect of ageing on the endodontic system, reserve crown, and roots of equine mandibular cheek teeth*, American Journal of Veterinary Research, 1996, 57, 31–38.
[15] KURYSZKO J., ZARZYCKI J., *Anatomia mikroskopowa zwierząt domowych i człowieka*, 1995, 116–120.
[16] MEHR K., JĘDRZEJEWSKI P., KOLASA M., *Elementy organiczne w szkliwie zębów ludzkich*, Nowiny Lek., 2000, 69, 3, 324–327.
[17] MUYLLE S., SIMOENS P., LAUWERS H., *The distribution of intratubular dentine in equine incisors: a scanning electron microscopic study*, Equine Vet. J., 2001, Jan 33, 65–9.
[18] PENCE P., *Equine dentistry a practical quide*, 2002, 1–23.
[19] SHELLIS P., *Dental tissue*, [in:] *Dental Anatomy and Embriology*, Blackwell Scientic Publications, 1981, 193–209.
[20] STANLEY H.R., WHITE, McCRAY, *The rate of tertiary (reparative) dentine formation in the human tooth*, Oral Surgery, Oral Medicine, Oral Pathology, 1966, 180–189.
[21] TEN CATE A.R., *Development of the tooth and its supporting tissues; hard tissue formation and its destruction; dentinogenesis*, Oral Histology, 1994, 111–119, 147–168.
[22] WAMSLEY J.P., *Some observations on the value of ageing 5–7-year-old horses by examination of their incisor teeth*, Equine Vet. Education, 1993, 5, 195–298.
[23] WEISS L., *Cell and Tissue Biology*, 602–638.