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Occlusal angles of equine cheek teeth

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ABSTRACT

The aim of this work was to determine occlusal cheek tooth angles in horses. The complex spatial shape of the equine skull hampers exact measurements of the occlusal cheek tooth angles in anatomical specimens and as well in living horses. Therefore a method was developed to perform measurements by using detailed 3D-reconstructions of equine skulls. 3D-models were constructed from CT-datasets by manual identification of relevant anatomical structures and by use of a computer software. Within 3D-skulls anatomical landmarks were identified and reference lines and planes were determined. Subsequently, occlusal angles of check teeth were measured in relation to the median plane. Results for mean values of cheek teeth angles ranged from 15.1° to 20.2°. Angles increased stepwise from rostral to caudal. Considering the total amount of data (20 horses with permanent dentition), there were no significant differences between the jaw quadrants when teeth in same Triadan positions were compared. However, in individuals there was a significant difference between the left and right side of the jaw. Angles of antagonistic teeth correlate with each other. The results are expected to provide a substantial basis for preventive and therapeutic treatments as well as for further biomechanical studies about equine mastication.

1. Introduction

A physiological cheek tooth occlusal angle is essential for a functional mastication and related forage utilization in the horse. Therefore, the target of correction of each type of malocclusion is to return to normal occlusion enabling a physiological mastication (Klugh, 2010). Certain pathological conditions of the occlusal surface geometry require rasping and therefore iatrogenic reduction of dental hard substances. Typical occlusal changes that are often corrected by use of motorized rasping equipment are conditions of partial dental overgrowth, i.e. sharp enamel points, hooks and ramps (Dixon et al., 1999). As a main reason for these conditions the lack of abrasive forage material in combination with a reduced time of mastication has been hypothesized (Dixon et al., 2000).

By treating dental overgrowth with electric rasps, it is not only necessary to correct the overgrown parts of the teeth, it is moreover mandatory to maintain or restore a normal and functional occlusal angle (Castell and Vogt, 2011). Accordingly, the determination of normal cheek tooth angles has been subject of several studies during the last decade.

Ralston et al. (2001) and Carmalt et al. (2005) measured the cheek tooth occlusal angle of tooth 307 or 406, respectively. In both studies a stiffened hinge metal plate

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was placed against the lingual and occlusal surfaces of the teeth and the occlusal angles were measured. Occlusal angles for tooth 307 ranged from 3° to 18° (Ralston et al., 2001). The angulation of tooth 406 was similar with a mean occlusal angle of 10.61° ± 7.1° (Carmalt et al., 2005).

Rucker (2004), Carmalt (2004) and Carmalt et al. (2005) applied an indirect method for measuring and calculating the occlusal angles by making a side excursion of the incisors, termed incisor separation angle technique (Carmalt, 2004). The average calculated angles, considered for the entire cheek tooth arcades, were 10° to 15° (Rucker, 2004) and 6.3° to 19° (Carmalt et al., 2005), respectively.

Brown et al. (2008) placed a stiff but malleable wire on the occlusal surfaces of the cheek teeth and subsequently transferred the outlines of the wires to graph paper. This method allowed to measure occlusal angles for each individual tooth of the cheek tooth arcades. Remarkably, a significant increase of the angulation was measured from rostral to caudal within each arcade. In the upper jaw angles of 11.8° (06 s) to 19.1° (11 s) were recorded, in the lower jaw even steeper angles, 18.4° (06 s) to 31.5° (11 s) were measured (Brown et al., 2008).

The wide ranges of premolar and molar occlusal angles were generally considered normal but angulations of more than 45° were recognized as pathological 'shear-mouth' (Dixon et al., 2000). Taken together, the results of these studies suggest a wide range of the occlusal angles with marked differences between teeth in different Triadan positions and with marked differences between antagonistic teeth of the upper and lower jaws. All these studies were performed in living horses or on anatomical specimens. However, measuring the correct cheek tooth angle in living horses – or in anatomical specimens – is hampered by the complex spatial shape of the skull, the movement of the head, even in sedated horses, and the enormous challenge to define – and reproducible use – a reference plane of repetitious accuracy. All of these methodological difficulties may influence the accuracy of the measurements. Therefore, the aim of this study was to develop a method which avoids the aforementioned difficulties and guarantees occlusal angle measurements of high accuracy in all teeth within a skull.

2. Material and methods

2.1. Creating 3D-models

Twenty equine skulls with permanent dentition, from warmblood and thoroughbred horses (no pony breeds were included) aged between 5 and 26 years (6 female and 14 male) were examined. Cheek teeth were termed according to the Triadan system using numbers from 06 (second premolar) to 11 (third molar).

Cadaveric heads were scanned by a CT system (BrillianceTM CT—Big Bore Oncology Scanner, Philips Medical Systems, Best, Netherlands). Datasets were provided by the Clinic for Horses of the University of Veterinary Medicine Hannover, Germany (for details, see Brinkschulte et al., 2013, 2014). DICOM datasets (Digital Imaging and Communications in Medicine) for each head contained between 450 and 500 2D-slices. By using the computer program Amira (version 5.4.2, Visage Imaging GmbH, Berlin, Germany) in each 2D-slice contrasts were adjusted to optimal visualization of mineralized hard substances. Subsequently, the outlines of the bony structures of the skull as well as the outlines of the teeth were identified and marked. Special attention was paid to a most accurate reproduction of the dental occlusal surfaces. Finally, datasets were converted to detailed 3D-models featuring the skull bones and the dentition.

For the purpose of measuring the occlusal angles, two sets of geometrical constructions were necessary, i.e. reference planes within the skull and lines/planes indicating the angulation of the occlusal surface of each tooth. Therefore, exact midline planes for the upper skull and for the mandible were created. Subsequently, lines and planes were determined on the occlusal surface of each tooth (Fig. 1).

2.2. Median planes

Each 3D-model was checked for the accurate representation of the following reference points/structures which are placed in the median plane of the skull:

Suture line of the ossa nasalia
Canalis interincisivus
Suture line of the Processūs palatinae of the ossa maxillaria
Crista sagittalis externa
Crista galli

These reference points were marked within the 3D-models and subsequently a median plane for the upper skull was calculated and visualized (Fig. 1).

A similar procedure was applied to calculate a median plane for the mandible. As the corpora of the mandible diverge, reference points placed in the median plane were rare and only present at the Sutura intermandibularis. Additional reference points within the median plane were created by use of bilateral anatomical structures of the mandible, i.e.: The midpoint of a line between the medial edges of the Capita mandibulae and the midpoint of a line between the medial edges of the Processūs coronoidei. Additionally, a line according to the bisecting angle of the diverging corpora of the mandible was calculated and visualized. Several points on this line were marked. Finally, all points served as a basis for the calculation and visualization of a median plane of the mandible (Fig. 1).

2.3. Occlusal surface - lines and planes

The enamel ridges of maxillary and mandibular cheek teeth feature a complex but very constant pattern. On maxillary as well as on mandibular cheek teeth, three well definied antomical points on the buccal edge and another three anatomical points at the lingual/palatal edge were marked (Fig. 2). Pairs of reference points (one buccal, one lingual/palatal) were used to create three occlusal lines with an buccal–lingual/palatal orientation. Additionally, all