A COMPLEMENTARY RADIOGRAPHIC PROJECTION OF THE EQUINE TEMPOROMANDIBULAR JOINT

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The complexity of the equine skull makes the temporomandibular joint a difficult area to evaluate radiographically. The goal of this study was to determine the optimal angle for a complementary radiographic projection of the equine temporomandibular joint based on a computed tomography (CT) cadaver study. CT was performed on six equine cadaver heads of horses that were euthanized for other reasons than temporomandibular joint disease. After the CT examination, 3D reconstruction of the equine skull was performed to subjectively determine the angle for a complementary radiographic projection of the temporomandibular joint. The angle was measured on the left and right temporomandibular joint of each head. Based on the measurements obtained from the CT images, a radiographic projection of the temporomandibular joint in a rostral45°ventral-caudodorsal oblique (R45°V-CdDO) direction was developed by placing the X-ray unit 30° laterally, maintaining at the same time the R45°V-CdDO angle (R45°V30°L-CdDLO). This radiographic projection was applied to all cadaver heads and on six live horses. In three of the live horses abnormal findings associated with the temporomandibular joint were detected. We conclude that this new radiographic projection of the temporomandibular joint provides superior visualization of the temporomandibular joint space and the articular surface of the mandibular condyle. *Veterinary Radiology & Ultrasound, Vol. 50, No. 4, 2009, pp 385–391.*

Key words: computer tomography, CT, equine temporomandibular joint, mandibular condyle, radiography.

Introduction

THE FEW REPORTS of temporomandibular joint disease in horses include degenerative changes, septic arthritis,[1–6] luxation,[7,8] fractures,[4,9,10] and experimental condylectomy.[11] There is a strong relationship between dental disorders and temporomandibular disease.[12–15] Reports of equine temporomandibular disease may not be more numerous because of the nonspecific nature of clinical signs[9] and difficulty in imaging temporomandibular joint radiographically.[2]

Recommended radiographic views of the temporomandibular joint consist of a left and right lateral, a ventrodorsal (VD), a dorsal60°lateral-ventrolateral oblique (D60°L-VLO) view or a modification of the latter.[16,20] Lesions which were most likely diagnosed with radiography include temporomandibular joint luxation[7,8] and fractures of the mandibular condyle.[4,9]

The complexity of the equine skull, and superimposition of structures, make the temporomandibular joint a difficult area to evaluate radiographically.[17–21] We have been assessing a complementary radiographic projection, which allows superior visualization of the equine temporomandibular joint, especially the mandibular condyle. However, the exact X-ray beam angle for this view is uncertain, and therefore this radiographic projection was not reproducible in different horses. The objective of this study was to determine the optimal angles for a complementary diagnostic radiographic projection of the equine temporomandibular joint based on a computed tomography (CT) cadaver study.

Materials and Methods

CT was performed on 12 temporomandibular joints of six horses, which were euthanized for reasons other than temporomandibular joint problems. There were three Thoroughbreds, one Standardbred, one Quarterhorse, and one Paint horse. Five horses were geldings and one was a mare. Age ranged between 3 and 13 years, with a median of 5.

CT imaging was performed using a third-generation helical CT scanner.* Each equine head, was scanned from the level of the fourth premolars to the most caudal aspect of the external occipital protuberance. A transverse helical image series with a collimation of 5 mm and a pitch of 1.4 was acquired using an exposure of 140 kV, 160 mA, and 1 s.

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*Pro Speed, General Electric Medical Systems, Milwaukee, WI.

To obtain better resolution of the temporomandibular joint, a transverse image series with a 2 mm collimation and 2 mm table increment was performed using an exposure of 140 kV, 160 mA, and 1 s, starting at the level of the second molars and continuing caudally to the most caudal aspect of the external occipital protuberance. For the helical as well as for the transverse scans, a high frequency image reconstruction algorithm (proprietary term "bone") and edge enhancement were used. The images were stored on an optical disc. The original DICOM images were exported into a DICOM viewer† and 3D volume rendering reconstruction of the skull performed. The angle for a radiographic projection of the temporomandibular joint was then obtained by placing the 3D reconstructed volume in a rostro-caudal direction with the nose tilted dorsally until the temporomandibular joint space was clearly visualized. To determine the direction of the X-ray beam for this view, the head was rotated back into a straight lateral view with the ventral border of the mandible being horizontal. Then a line, representing the course of the X-ray beam was drawn subjectively tangential to the mandibular condyle in the middle of the rostral aspect of the temporomandibular joint space. An additional line was drawn parallel to the horizontal surface and the angle between the drawn line through the temporomandibular joint space and the horizontal baseline was calculated (Fig. 1). The described angle was determined for both the left and right temporomandibular joint of all six horses. All images were evaluated three times by the same person (A.E.) and the average of the triple measurements was used for statistical evaluation.

Radiography was performed using an indirect capture digital radiography system.‡ The horse heads, which were kept frozen at −17°C before the radiographic examination, were placed on a table in ventral recumbency. Based on the results of the CT study, the X-ray tube was positioned in a rostral45°ventral-caudodorsal oblique (R45°V-CdDO) direction. The imaging plate was placed in a cassette holder and positioned on the occipital protuberance at an angle of 15° to the horizontal surface of the table and an angle of 120° to the X-ray beam. This angle was used to mimic the continuation of the neck in live horses. The X-ray beam was then centered on the left temporomandibular joint with a focus-to-film distance of 80 cm. Settings of 80 kV and 10 mA were chosen. To optimize visualization of the temporomandibular joint, four further radiographic projections were tested by additionally angling the X-ray beam to the side by 10°, 20°, 30°, and 40° maintaining the R45°V-CdDO direction of the central beam (Fig. 2A and B). The five radiographic projections were applied to the left and right temporomandibular joint of all six cadaver heads.

†OsiriX Foundation, Geneva, Switzerland.

‡Canon CXDI—31plate, RapidStudy™ EDR5, Eklin Medical System Inc., CA.

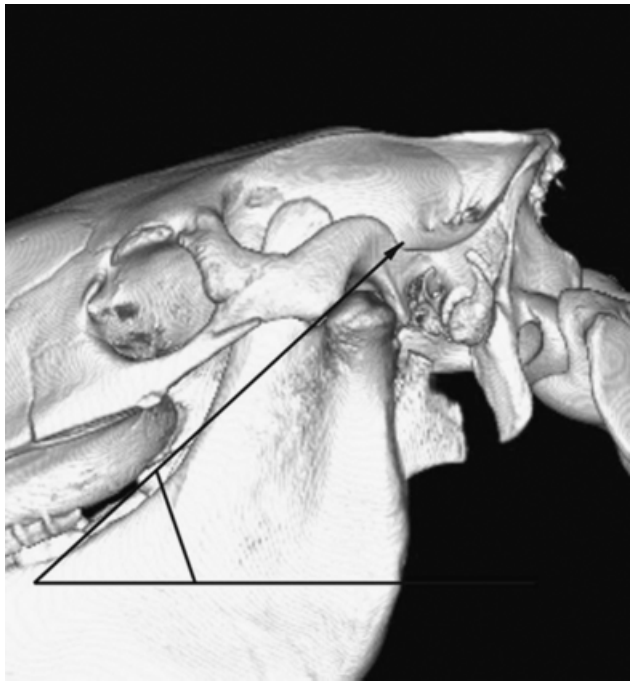

FIG. 1. Lateral view of the 3D reconstruction of the left temporomandibular joint. The arrow representing the course of the X-ray beam was drawn through the middle of the rostral aspect of the temporomandibular joint space and tangential to the articular surface of the mandibular condyle. A second line was drawn parallel to the horizontal surface and the angle between the two lines was calculated.

After the cadaver investigation was completed, the new radiographic projection was tested on six live horses. The live horses consisted of one Thoroughbred, one Icelandic pony, one Arabian, and three Warmbloods. There were four geldings and two mares. Age ranged between 6 and 27 years, with a median of 11.75. Three of the six horses had clinical signs suspicious for temporomandibular joint disease. Two had a history of mastication disorders for 2 days and 2 weeks, respectively. The latter one also had a swelling in the region of the left temporomandibular joint. The third horse had pharyngeal–esophageal obstruction. Two of the remaining horses were presented for their annual dental care and the remaining horse was healthy (Table 1).

For correct radiographic positioning of the head, the live horses were sedated and the rostral aspect of the mandible was placed on a post so that the ventral border of the body of the mandible was horizontal (Fig. 3). The optimal projection obtained from the cadaver study was used to image the temporomandibular joint of the live horses. In the horse with the temporomandibular joint region swelling additional radiographic views consisting of a VD, and a left and right 30° caudal to cranial oblique projection were obtained. The radiographic DICOM images were imported into the Picture Archiving and Communication system

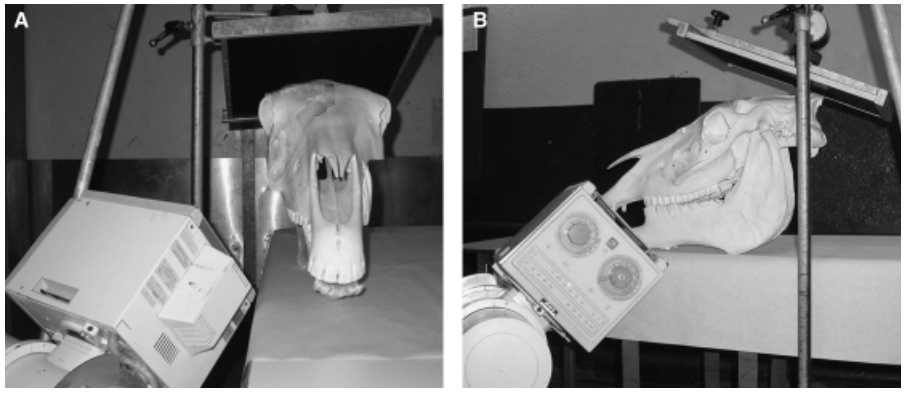

FIG. 2. (A) and (B) Positioning of the X-ray unit and skull for the R45°V30°L-CdDLO projection of the temporomandibular joint. The X-ray beam is centered on the temporomandibular joint, the imaging plate is placed on the occipital protuberance and is angled 15° rostrally.

(PACS),§ where they were evaluated. The DICOM images were also imported into the DICOM viewer, exported as .tiff-files on a CD and then imported into Adobe Photoshop¶ to change filter settings and gradation curves. The manipulated images were then stored as .tiff-files.

Statistical analysis was performed using descriptive statistics. Median, minimum, and maximum were calculated from all measured parameters. The angles of the rostral aspect of the left temporomandibular joint were compared with the ones from the right, by using one-way analysis of variance with NCSS.‖ The level of significance was $P<0.05$ for comparison of the left to the right temporomandibular joint.

Results

There were no bone or soft tissue abnormalities of the temporomandibular joint in any CT image from the cadaver specimens or in the living horses. The angle of the rostral aspect of the right temporomandibular joint ranged between 40° and 50° with a median of 44.5°. The angle of the rostral aspect of the left temporomandibular joint ranged between 42° and 51° with a median of 45°. This difference was not statistically significant ($P=0.48$).

The temporomandibular joint space was clearly identified on all radiographic images of the examined horses. There were no radiographic abnormalities of the temporomandibular joint in the cadaver specimens. The R45°V-CdDO and R45°V10°L-CdDLO projections were characterized by superimposition of the os zygomaticum, os temporale, and the coronoid process of the mandible with the axial aspect of the temporomandibular joint (Fig. 4A). Angling the X-ray beam to the side improved visualization of the temporomandibular joint space and the mandibular condyle by decreasing superimposition (Fig. 4B). The most diagnostic radiographic projection was achieved by directing the X-ray beam in a R45°V30°L-CdDLO direction. Directing the X-ray beam at R45°V40°L-CdDLO resulted in minor superimposition of the parietal bone with the axial aspect of the temporomandibular joint and the mandibular condyle (Fig. 4C).

The radiographic findings of the temporomandibular joints of the live horse group included an interruption with a 1 cm deep lucency surrounded by a sclerotic zone in the mid aspect of the subchondral bone in the right mandibular condyle of a healthy horse (Fig. 5) and a mild irregular thickened subchondral bone of the left mandibular condyle in the horse with the pharyngeal–esophageal obstruction (Fig. 6). The horse with swelling in the left temporomandibular region and the mastication disorder had diffuse reduction in the radiopacity of the mandibular condyle and the zygomatic process of the temporal bone with a sequestrum in the subchondral bone of the zygomatic process. A marked irregular shaped, radiolucent periarticular defect in the proximal and lateral aspect of the left mandibular condyle as well as irregular periostal proliferation along the zygomatic process of the left temporal bone could also be seen (Fig. 7A). Septic arthritis was confirmed. One radiographic image of the right temporomandibular joint of one of the horses presented for dental examination was of decreased radiographic quality due to motion artifacts.

Discussion

Although CT and magnetic resonance imaging are superior to radiography for visualization of the temporomandibular joint, radiography will likely remain the first-line modality used to image this area. Up to now, the described radiographic projections of the temporomandibular joint allowed detection of gross lesions such as mandibular condylar fractures[7,8] or luxation.[4,9]

§iSite PACS, Koninklijke Philips Electronics N.V., Eindhoven, the Netherlands.

¶Adobe Photoshop Elements 4.0, Adobe Systems Incorporated, San Jose, CA.

‖Number Cruncher Statistical Systems, Kaysville, UT.

TABLE 1. Summary of the Live Horses Introduced into the Study

	Breed	Sex	Age (years)	Diagnosis	Radiographic Abnormalities of the Right TMJ	Radiographic Abnormalities of the Left TMJ
1	Thoroughbred	G	6	Healthy	Yes, interruption with a 1 cm deep lucency surrounded by a sclerotic zone in the mid aspect of the subchondral bone of the right mandibular condyle	No
2	Warmblood	M	11.5	Annual dental care, healthy	No	No
3	Warmblood	M	18	Annual dental care, healthy	Not diagnostic	No
4	Icelandic Pony	G	27	Pharyngeal–esophageal obstruction	No	Yes, mild irregular thickened subchondral bone in the right mandibular condyle
5	Arabian	M	6	Fracture in the body of the left mandible	No	No
6	Warmblood	G	12	Septic arthritis of the left TMJ	No	Yes, diffuse reduction in the radiopacity of the mandibular condyle and the zygomatic process of the temporal bone, periarticular defect in the proximal and lateral aspect of the mandibular condyle, moderate periostal proliferation along the lateral aspect of the mandibular condyle and the zygomatic process as well as a sequestrum in the subchondral bone of the zygomatic process of the temporal bone

G, gelding; M, mare.

The radiographic projections described in this study contribute to a more complete examination of the temporomandibular joint, especially the mandibular condyle and its subchondral bone plate, by reducing superimposition of the previously described ipsilateral bony structures as well as the contralateral aspect of the skull.

FIG. 3. Positioning of the head on the post and the placement of the cassette holder. Notice that the ventral border of the mandible is parallel to the horizontal surface.

The 3D reconstruction of the equine skull was valuable for better understanding the osseous relationships of the area of the temporomandibular joint and was essential for calculation of the X-ray beam angle of this complementary projection. We found that directing the X-ray beam at a R45°V-CdDO angle allows for a valuable projection of the temporomandibular joint space. Based on the CT assessment, we believe there is a small acceptable range of approximately 5° for this particular angle. If the RV-CdDO angle is significantly greater or less than 45°, the X-ray beam will not be tangential to the rostral aspect of the temporomandibular joint space. Consequently, the zygomatic process of the temporal bone will overlap the mandibular condyle and the temporomandibular joint space will not be visible.

When the X-ray beam is directed in a R45°V-CdDO angle, there is significant superimposition of the zygomatic bone with the axial aspect of the temporomandibular joint. By angling the X-ray unit to the side by 20–30°, superimposition of the os zygomaticum, os temporale, and the coronoid process of the mandible can be avoided and the temporomandibular joint as well as the mandibular condyle can be better visualized.

Owing to the anatomic position of the equine head and neck, perpendicular orientation of the X-ray imaging plate to the X-ray beam is impossible. Instead, the imaging plate is placed at a 120° angle to the X-ray beam, which results in distortion of the temporomandibular joint, especially of the mandibular condyle. This artifact is unlikely to com-

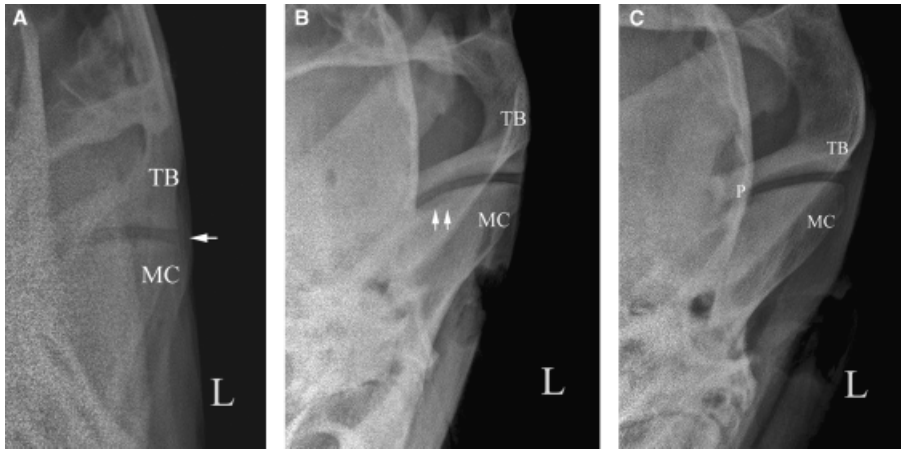

FIG. 4. (A) Radiograph of the left temporomandibular joint, made using a R45°V-CdDO orientation. The temporomandibular joint space (white arrow head) is clearly visible, however, there is significant superimposition of the os zygomaticum, os temporale, and the coronoid process of the mandible with the axial aspect of the temporomandibular joint. TB, temporal bone; MC, mandibular condyle; (B) Radiograph made using a R45°V30°L-CdDLO angle. Note the significant decrease in superimposition with the axial aspect of the temporomandibular joint space and the mandibular condyle (double arrows) when compared with part (A). (C) Radiograph of the left temporomandibular joint. The X-ray beam was in a R45°V40°L-CdDLO orientation. There is more superimposition of the temporomandibular joint space with the parietal bone (P) when comparing this image with the projection acquired at a R45°V30° L-CdDLO angle in part (B).

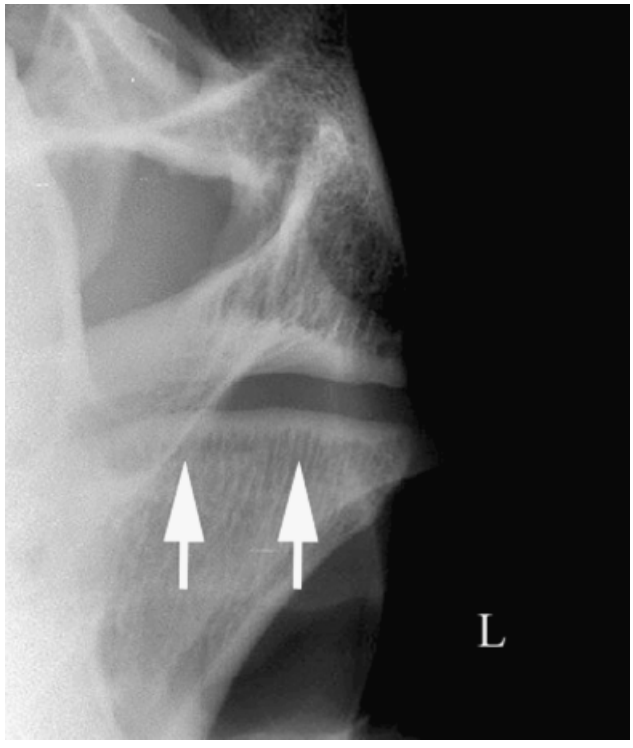

FIG. 6. Radiographic projection in a R45°V30°Rt-CdDLeO direction of the left temporomandibular joint in the horse with the pharyngeal–esophageal obstruction. Note the mild irregular thickened subchondral bone in the right mandibular condyle (white arrows).

FIG. 5. Radiograph of one of the live horses without temporomandibular disease using a R45°V30°Le-CdDRtO orientation of the X-ray beam. An interruption with a 1 cm deep lucency (white arrow head) with a sclerotic rim is visible in the subchondral bone surface of the mandibular condyle.

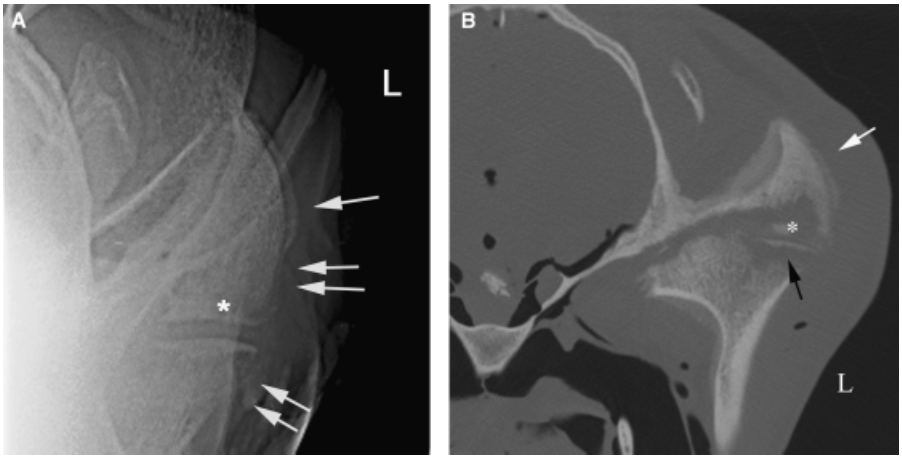

FIG. 7. (A) Radiograph of the left temporomandibular joint of the horse with septic arthritis placing the X-ray unit in a R45°V30°Rt-CdDLeO direction. There is diffuse radiolucency of the mandibular condyle and the zygomatic process of the temporal bone (double arrows) with a marked irregular shaped, radiolucent periarticular defect in the proximal and lateral aspect of the left mandibular condyle as well irregular periostal proliferation along the zygomatic process of the left temporal bone (single arrow). A sequestrum in the zygomatic process is visible (asterisk). (B) CT axillary image of the equine skull at the level of the left temporomandibular joint in the same horse. Note the mildly irregular periostal proliferation along the temporal bone (single white arrow) and the mandibular condyle. There are also large areas of erosion in the mandibular condyle and the zygomatic process of the temporal bone and a periarticular defect in the proximal and lateral aspect of the left mandibular condyle. There is also an articular fragment of the mandibular condyle (black arrow). Note the previously described sequestrum (asterisk).

promise the diagnostic value of this new radiographic projection, but it must be kept in mind when the temporomandibular joint is interpreted using this particular view.

The majority of horses tolerated the new projection very well. To achieve maximal radiation safety, we placed the imaging plate in a cassette holder and positioned it over the occipital protuberance of the head, which was resting on a support post. One horse was very sensitive to the noise of the X-ray unit and moved the head dorsally, striking the imaging plate. As this particular horse already received several sedatives that day, we decided to discontinue the radiographic examination.

It is reported that the mandibular condyle angles at 15° in two planes, from dorsolateral–ventromedial and from caudomedial–rostrolateral.[13] The R45°V-CdDO angle of the rostral aspect of the temporomandibular joint space appears to be an additional angle associated with the mandibular condyle that is found to be similar throughout horses of different breeds and ages.

A limitation of this study is that the cadaver specimens were not inspected grossly. Although those horses had a normal CT and radiographic appearance of the temporomandibular joints, they might have had subtle changes in the articular surface of the mandibular condyle or the zygomatic process of the temporal bone which would not have been conspicuous in the CT images. Another limitation is that the number of horses in this study is small. As the described projections were applicable throughout all the examined horses, we assume that a successful projection of the temporomandibular joint does not depend on the breed or age of the horse and that it will be applicable throughout the majority of horses.

In conclusion, a radiographic projection in a R45°V30° L-CdDLO direction allows more complete radiographic evaluation of the equine temporomandibular joint. This projection is an feasible, and noninvasive and should be evaluated in horses suspected of having temporomandibular disease.

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