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# Assessment of five oblique radiographic projections of the canine temporomandibular joint.

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**Abstract**

Investigation of Temporomandibular Joint (TMJ) disease requires a clear diagnostic image, which can be challenging to obtain using conventional radiography. The aim of this study was to compare five different oblique radiographic views with the head in lateral recumbency, assessing the clarity of visualization of the normal TMJ anatomy.

The views under investigation were the laterorostral-laterocaudal oblique at a 10° and 20° rotation of the head ("nose-up" view), laterorostral-laterocaudal oblique with a rostro-caudal x-ray beam angulation of 10° and 20°, and a parallax view with the beam centered over C2 and collimated to include the TMJ region, using the divergence of the x-ray beam to project the TMJs separately on the radiograph. The views were performed on both TMJs of thirty canine cadavers and were graded independently by experienced and inexperienced observers. Grading was performed on the mandibular fossa, condylar process, joint space, retroarticular process and the overall TMJ, and was based on a four point scale. Mean grades for each component and for the overall joint were compared for each observer and each projection.

Mean grades were significantly ($p<0.05$) higher for the “Nose-up” projections than the angled beam or parallax projections, as was interobserver agreement, and both observers showed significantly higher ($p<0.05$) mean grades for the $20^{o}$ “Nose-up” angulation than the $10^{o}$ “Nose-up” angulation.

These results suggest that a latero $20^{o}$ rostral-laterocaudal oblique gives the best representation of the anatomy of the TMJ of the dog of the projections assessed, and should be considered when investigating clinical cases of TMJ disease.

**Introduction**

The canine temporomandibular joint (TMJ) is formed by the condylar process of the mandible and the mandibular fossa of the temporal bone (which extends ventrally into the retroarticular process).[1-3] It is a synovial joint, and in the dog contains a rudimentary fibrocartilagenous disc – this is of little functional significance in the carnivores, but is much more developed and has a greater significance in the herbivores.[2] The formation of the canine TMJ is such that it is limited to a hinge like action (due to the rounded shape of the condylar process and corresponding mandibular fossa and retroarticular process), allowing a strong slicing action of the jaws and maximal shearing efficiency of the carnassial teeth.[1,2]

Diseases of the temporomandibular joint are fairly uncommon in the dog. These may include traumatic injuries to the joint (luxation, fracture), degenerative joint disease (which may progress to ankylosis), dysplasia (which may present as open-mouth jaw locking), septic arthritis/osteomyelitis and neoplasia.[3-9] Symptoms of TMJ disease may include reduced appetite, pain on opening the jaw and reduced range of lower jaw movement (difficulty opening or closing the mouth). With luxations or dysplasia the jaw may lock in the open position, with the mouth unable to close.[5]

Radiography of the canine TMJ can be technically challenging.[3,4] While advanced imaging techniques such as computed tomography can give excellent images of the TMJ (and may allow three-dimensional and multiplanar reconstructions), the availability of such scanners is limited in veterinary practice (due to available facilities and/or cost), whereas conventional radiography remains the most widely available imaging modality.[3,10] However radiography of the TMJ presents several difficulties, including the superimposition of other skull structures such as the calvarium on dorsoventral radiographs and the other TMJ on lateral radiographs.[3,4] To adequately visualize the individual TMJs on lateral projections requires the use of oblique lateral radiographic projections to reduce this superimposition. Potential radiographic projections include Latero $10^{o}$ Rostral-Laterocaudal and Latero $20^{o}$ Rostral-Laterocaudal oblique projections – these may be obtained by either raising the nose from the lateral by the required angle (using foam wedges and a vertically-orientated x-ray beam) or by angling the x-ray tube from the vertical by the appropriate angle.[3,4] An alternative method to obtain separate lateral projections of the TMJs is a parallax technique – by centering caudal to the head, the divergence of the x-ray beam results in separation of the images of the TMJs.[3] Unlike the Laterorostral-Laterocaudal oblique projections, where the dependent TMJ is projected more rostrally, using this parallax technique the non-dependent TMJ will be projected more rostrally, with the increased object-film separation leading to greater magnification of the TMJ, along with a slight loss of edge sharpness due to a greater penumbra.[11]

The aim of this study was to compare the clarity of the TMJ images in terms of visualization of normal anatomic structures produced by Laterorostral-Laterocaudal projections at $10^{o}$ and $20^{o}$ with either the nose raised or the x-ray tube angled and by images using the parallax technique. The hypothesis was that images obtained using the parallax technique would provide at least as good an image of the TMJ anatomy as the other techniques investigated.

**Materials and Methods**

A brief initial study using a mounted canine skeleton was used to assess the optimal centering point for the parallax projection. Lateral-lateral radiographs were obtained with the vertically-orientated x-ray beam centered on the mid-point of each of the cervical vertebrae from C1 to C5 – the film cassette was placed underneath the skull with the skeleton positioned in lateral recumbency for each projection. Centering caudal to C5 was not possible due to collimation limitations. Radiographs were assessed consensually by two observers (one board-certified imaging specialist, one veterinary undergraduate student) immediately following completion of radiography, and the consensus centering point for optimal image clarity was used in the subsequent study.

The main part of the study used 30 skeletally mature mesaticephalic or dolichocephalic canine cadavers euthanized for reasons unconnected to the ear. Both TMJs of each cadaver were radiographed in five different projections:

i) Latero $20^o$ Rostral-Laterocaudal Oblique with Nose Raised (“Nose Up $20^o$”)
   - Le20R-RtCdO for the right TMJ and Rt20R-LeCdO for the left
ii) Latero $10^o$ Rostral-Laterocaudal Oblique with Nose Raised (“Nose Up $10^o$”)
   - Le10R-RtCdO for the right TMJ and Rt10R-LeCdO for the left
iii) Latero $20^o$ Rostral-Laterocaudal Oblique with Tube Angled (“Tube $20^o$”)
   - Le20R-RtCdO for the right TMJ and Rt20R-LeCdO for the left
iv) Latero $10^o$ Rostral-Laterocaudal Oblique with Tube Angled (“Tube $10^o$”)
   - Le10R-RtCdO for the right TMJ and Rt10R-LeCdO for the left
v) Parallax with x-ray beam centered on C2 (“Parallax”)
   - Left lateral recumbency to demonstrate the right TMJ, and right lateral recumbency to demonstrate the left TMJ

Positioning and stabilization of the heads was performed using foam positioning wedges. The alignment of the philtrum of the nose and base of the mandibles with the table top were used to position the heads in true lateral recumbency (for the parallax and oblique projections obtained with the angled x-ray tube), and foam wedges were placed under the dependent aspect of the head to raise the nose to the required degree (while avoiding axial rotation) for the projections with the nose raised from the table. A tube angle indicator was present on the x-ray machine tube, and a goniometer was used to measure the angles when the nose was raised – the midline sagittal plane of the lower jaw was identified, and the angle between this and the table top was measured.

This gave a total of 60 TMJs, each radiographed in five projections (with a total of 300 radiographs). The mouths of the cadavers were closed during the radiographic study. Radiographs were checked for radiographic quality, and were grouped by projection. All radiography was performed by a single author who subjectively assessed the relative ease of performing each radiographic technique. All radiography was performed with a single x-ray machine[*], using the same film-screen combination[†] and a predetermined exposure chart based on the thickness of tissue to be imaged (measured using calipers).

Once all radiography was complete, the radiographs were independently graded by two observers (one board certified imaging specialist and one undergraduate veterinary student). Four individual components of the temporomandibular joint (Joint Space, Retroarticular process, Mandibular fossa and Condylar Process of the Mandible) were graded from 0 to 3 based on the scheme below:

0 = Not Visible
1 = Identifiable, but margins not visible
2 = Identifiable with margins partially seen
3 = Identifiable with clear margins

An overall grade between 0 and 3 was then allocated to each TMJ (dependent on the clarity of the components detailed above) based on the scheme below:

0 = TMJ not identified
1 = TMJ identified, but individual components not distinguished

[*] Villa Sistemi Medicali Genius HF, Buccinasco, Italy
[†] Curix Ortho Fine and Curix HT1.000G Plus, AGFA-Gevaert, Mortsel, Belgium.

2 = TMJ identified with individual components identified but not clearly seen

3 = TMJ identified with easy recognition of individual components

Examples of TMJ radiographs allocated overall grades of 1, 2 or 3 are demonstrated in Figure 1.

Once all scoring was complete, scores from each observer were compared using a paired t-test, and interobserver agreement for each sets of scores was assessed using Cohen's kappa. Statistical analysis was performed by one of the authors, using a spreadsheet programme with integrated statistical analysis package[‡].

**Results**

The consensual assessment of the results of the preliminary study demonstrated that radiographs centered on C2 were likely to give the clearest parallax projections of the TMJ. Centering further cranially resulted in excessive superimposition of the TMJs, and centering further caudally resulted in unacceptably distorted images of the TMJ structures. It was determined that for practical purposes, palpating the wings of C1 and centering slightly caudal to this point would give the most consistent method of centering for the parallax projection in the cadavers.

The mean scores (0-3) from each observer for the four individual TMJ components and for the overall TMJ score are presented in Table 1. No TMJ was given an overall score of 0 (i.e. all TMJs could be identified), and there was at least one TMJ given an overall grade 3 in each projection group. For all components except for the retroarticular process on the "Nose Up $10^{o}$" and "Tube $10^{o}$" projections (where there was no significant interobserver difference), and for the overall TMJ scores, observer B (the veterinary undergraduate student)'s

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‡ Microsoft® Office Excel 2003, Microsoft Corporation.

mean scores were significantly ($p<0.05$) higher than those for observer A (the imaging diplomate). For both observers, the overall mean score for the "Nose Up $20^{o}$" was significantly ($p<0.05$) higher than the mean scores for the other projections.

For the individual components, the "Nose Up $20^{o}$" gave significantly higher ($p<0.05$) scores when compared to the other projections except for the temporal fossa when compared to the "Nose Up $10^{0}$", and the retroarticular process when compared to the "Nose Up $10^{o}$" and "Tube $20^{o}$" projections.

The results of the interobserver agreement are presented in Table 2. The agreement for the "Nose Up" projections ($10^{0}$ and $20^{0}$) was moderate, whereas that for the other projections was only fair – however there was not a statistically significant difference between the projections.

The observer performing the radiographic procedures felt that the "parallax" projections were consistently the easiest to obtain, due to the relative ease of positioning the head (in true lateral recumbency) and ease of centering the x-ray beam, although the positioning of the radiographic cassette required some care (to ensure the image of the TMJ was produced on the film). The "Nose Up" projections were consistently the most technically challenging, due to the care required to ensure the head was angled correctly without axial rotation, and then identifying the correct centering point. The projections taken with the x-ray tube angled were relatively simple in terms of positioning the head and x-ray machine tube (due to the presence of a tube angle indicator), but more challenging in identifying the correct point for centering, and also presented a challenge in correctly positioning the cassette to obtain the required image.

## Discussion

Radiography of the temporomandibular joint presents many challenges, and achieving good representation of the anatomy of the TMJ on the radiograph is critical in diagnosing abnormalities of the joint.[3,4] While both TMJs can be seen on a dorsoventral or ventrodorsal radiograph of the skull, assessing the joint space and retroarticular process adequately requires a lateral projection, which has to have some obliquity to prevent superimposition of the left and right TMJs, and also to allow a clear view of the joint space – the TMJ of the dog typically has a rostromedial-caudolateral angulation.[1,3,4] The purpose of this study was to assess five different techniques for obtaining lateral oblique projections of the TMJ.

The ideal radiographic projection of the TMJ will give good anatomic reproduction of the joint structures, while at the same time being technically easy to perform – unfortunately from the findings of this study these two features are mutually exclusive as the projection giving the combination of best average score and joint-best interobserver agreement was subjectively judged to be the most challenging to perform (the “Nose-up $20^{0}$” projection). The true difficulty in positioning the dogs for radiography could have been misrepresented as the cadavers used in this study may have been more difficult to position (due to residual rigor mortis or other compromising factors) than live patients, although a live patient may have anaesthetic equipment (e.g. endotracheal tube) in place which may in itself cause difficulties in positioning or serve to obscure the TMJ on the resulting radiograph.

The “Nose Up $20^{0}$” projection was given both the best overall results by both observers, and also generally the best results for the four individual components of the TMJ. This suggests that this projection gives the most consistent anatomic representation of the temporomandibular joint of the projections tested. The “Nose Up $10^{o}$” projection gave the next most consistent imaging of the TMJ structures, although the interobserver agreement was actually slightly (although not statistically significantly) higher than the “Nose Up $20^{o}$” projection. The authors suggest that this is a combination of centering the x-ray beam directly over the area of the TMJs and also minimizing the x-ray beam divergence once it has passed through the TMJs – these will combine to minimize the distortion of the resulting image. For both the angled tube and parallax projection techniques, there will be a greater degree of beam divergence once the beam has passed through the TMJ, and this will create a more distorted image. This distortion will be increased through the beam not being centred on the TMJ for the parallax projection. In addition, assessing the correct exposure factors was easiest for the “Nose-up” projections, where a more accurate measurement of the thickness of tissue the x-ray beam was to pass through was possible than with the other projections. These findings support previous studies on the effect of obliquity on the radiographic appearance of the TMJ, where rotation angles of 10-30$^{o}$ were recommended in mesaticephalic and dolichocephalic breeds.[12]

As well as the rostromedial-caudolateral angulation of the canine temporomandibular joint, there is usually a degree of dorsolateral-ventromedial angulation (generally $<10^{o}$). Although the effect of this angulation on the clarity of the resulting images was not investigated as part of this study, laterodorsal-lateroventral oblique projections (with rotation of the head about the long axis) have been suggested as alternate techniques for imaging the temporomandibular joints.[3,12] Previous work has suggested angles of 10-30$^{o}$ from the true lateral-lateral projection give optimal images of the TMJ using these techniques.[12]

In terms of technical ease of obtaining the projection, the parallax projection was felt to be the easiest to obtain, as it was simply a case of placing the animal in lateral recumbency and palpating the lateral process of C1 to identify the centering point[3]. The oblique projection obtained by angling the x-ray tube head was the next easiest, again largely due to maintaining the head in lateral recumbency. For this projection, identifying the centering point was more complex, and care had to be taken with the position of the cassette, which had to be placed slightly caudal to the level of the TMJs to allow for the direction of the x-ray beam – this positioned was determined by using the light beam diaphragm to predict the path of the x-ray beam. The oblique projection with the nose raised was the most technically challenging, requiring the nose to be angled by a set degree and supported by a foam wedge, while preventing axial rotation of the head. However it was felt that centering for this projection was slightly easier than centering with the angled x-ray tube, and as mentioned above, determining the correct exposure factors was simpler for this projection.

For almost all of the anatomic structures assessed there was a significant difference ($p<0.05$) between the two observers, with Observer B (the undergraduate) scoring higher than observer A. The authors believe this to be associated with relative experience and confidence in image interpretation skills. Discussion between the authors determined that the undergraduate felt that if he were able to identify the TMJ structures, the representation of the structures on the radiograph must be of high quality, and so these were allocated a high score. Observer A, with considerably greater radiological experience, was more discriminating, and so tended to allocate lower scores to the various structures. Further image interpretation by individuals with varying levels of radiological experience may help to confirm this suspicion.

There are several limitations of this study. The lack of brachycephalic canine cadavers in the study population means that the optimal angles for radiography of the TMJ in these breeds cannot be assessed, but previous work suggests optimal positioning for brachycephalic dogs may require slightly greater angles of rotation than mesaticephalic or dolichocephalic animals.[12] In addition, this study did not investigate the effects of long-axis rotation of the head on the quality of the TMJ images produced. In this study, the aim was to test the parallax projection against other oblique projections, and it was felt that this was best done against radiographs obtained with lateral rotation of the head (or x-ray tube) as these would produce the projection of the TMJ anatomy closest to that generated by the parallax technique. A final possible limitation was that the cadavers were radiographed with the mouths closed. A significant amount of cranial radiography will be performed with the patients under general anaesthesia (and so with the mouth open to accommodate the endotracheal tube), and this will alter the relationship between the condylar process of the mandible and mandibular fossa of the temporal bone, and hence the appearance of the TMJ on radiographs.

In conclusion, this study suggests that when obtaining lateral radiographs of the canine TMJ, a Latero $20^{o}$ Rostral-Laterocaudal projection obtained with a vertically orientated x-ray beam and the nose elevated from the table top (by $20^{0}$)

is likely to provide the optimal radiographic representation of the anatomic structures of the joint, although this can be a technically challenging radiographic projection to obtain.

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## Table Legends

**Table 1:** Mean Scores (0-3) for Observers for individual joint components and for the overall temporomandibular joints for the five different radiographic projections assessed.

**Table 2:** Interobserver Agreement for the five different radiographic projections being assessed.

## Figure Legend

**Figure 1:** Example images showing radiographs of the canine temporomandibular joint that were allocated overall scores of 1 (Figure 1A), 2 (Figure 1B) and 3 (Figure 1C).

# Assessment of five oblique radiographic projections of the canine temporomandibular joint.

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| | | Observer A | Observer B |
|---|---|---|---|
| Nose up 10o | Temporal Fossa | 1.53 | 2.12 |
| | Condylar Process | 1.85 | 2.28 |
| | Joint Space | 1.43 | 2.07 |
| | Retroarticular Process | 2.05 | 2.15 |
| | **Overall TMJ** | **2.03** | **2.32** |
| Nose up 20o | Temporal Fossa | 1.67 | 2.42 |
| | Condylar Process | 2.00 | 2.53 |
| | Joint Space | 1.68 | 2.40 |
| | Retroarticular Process | 2.08 | 2.43 |
| | **Overall TMJ** | **2.25** | **2.50** |
| Tube 10o | Temporal Fossa | 1.08 | 1.60 |
| | Condylar Process | 1.52 | 1.85 |
| | Joint Space | 1.03 | 1.62 |
| | Retroarticular Process | 1.73 | 1.60 |
| | **Overall TMJ** | **1.58** | **1.85** |
| Tube 20o | Temporal Fossa | 1.20 | 2.10 |
| | Condylar Process | 1.57 | 2.27 |
| | Joint Space | 1.25 | 2.07 |
| | Retroarticular Process | 1.97 | 2.17 |
| | **Overall TMJ** | **1.75** | **2.27** |
| Parallax | Temporal Fossa | 1.38 | 2.07 |
| | Condylar Process | 1.57 | 2.17 |
| | Joint Space | 1.03 | 2.02 |
| | Retroarticular Process | 1.73 | 1.97 |
| | **Overall TMJ** | **1.72** | **2.13** |

**Table 1: Mean Scores (0-3) for Observers for individual joint components and for the overall temporomandibular joints for the five different radiographic projections assessed.**

| Projection | Kappa | Range (95% CI) | Agreement |
|---|---|---|---|
| **Nose up 10$^o$** | 0.576 | 0.406-0.745 | Moderate |
| **Nose up 20$^o$** | 0.537 | 0.353-0.720 | Moderate |
| **Tube 10$^o$** | 0.299 | 0.121-0.476 | Fair |
| **Tube 20$^o$** | 0.241 | 0.091-0.392 | Fair |
| **Parallax** | 0.339 | 0.181-0.497 | Fair |

**Table 2 – Interobserver Agreement for the five different radiographic projections being assessed.**