Vet.Med.J.,Giza. Vol.54, No.2. (2006) : 359-378.

CONVENTIONAL PLAIN AND POSITIVE CONTRAST RADIOGRAPHIC IMAGING OF THE SKULL IN DOGS AND CATS

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Received: 16.11.2005.
Accepted: 27.11.2005.

SUMMARY

This study was carried out on 50 apparently healthy animals (30 dogs and 20 cats) and 15 dogs suffered from skull affections. Animals were subjected to Conventional plain radiographic imaging (lateral, dorsoventral, rostrocaudal, lateral oblique, open-mouth rostrocaudal, open-mouth lateral, open-mouth ventrodorsal and intra-oral positionings). Also, positive contrast canalography and rhinography were done to visualize, in details, the acoustic canal and nasal structures respectively. The results revealed that the evaluated Conventional plain radiographic positionings were efficient for imaging the skull anatomy and its affections. Canalography can be regarded as an accurate technique to measure the diameter of the horizontal ear canal and the tympanic membrane which are predictors of ear diseases. Rhinography was found to be valuable in imaging of nasal sinuses and conchae.

INTRODUCTION

The skull is one of the most complex and specialized parts of the axial skeleton to capture and interpret radiographically. Conventional plain multiple radiographic projections are essential for adequate evaluation of the skull anatomy and for accurate diagnosis of its abnormalities (Donald, 1986; Burk and Ackerman, 1996; Hecht, 2003; Bischoff and Kneller, 2004; Mattoon and Drost, 2004 and Gioso et al, 2005).

Positive contrast canalography is an accurate and sensitive radiographic method used for viewing the anatomical appearance and characteristics of the horizontal ear canal, tympanic membrane, tympanic bulla and other parts of the ear (Dickie et al. 2003, Garosi et al. 2003 and Bischoff and Kneller, 2004). For nasal structures, the positive contrast rhinography is indicated for the evaluation of nasal cavity, nasopharynx and paranasal sinuses. It is considered the most accurate procedure for diagnosis of chronic nasal diseases (Park et al. 1992; Codner et al. 1993 and Saunders, et al. 2004).

The aim of this study was to evaluate the efficacy of conventional plain radiographic positioning and the advantages of using positive contrast canalographic and rhinographic techniques in radiographic imaging of the skull in dogs and cats.

MATERIAL AND METHODS

This study was performed on 50 apparently healthy animals (30 dogs and 20 cats) and 15 dogs suffered from skull affections that were examined at the department of Surgery, Anaesthesiology and Radiology, Faculty of Veterinary Medicine, Cairo University. All animals were premedicatied with a combination of Atropine sulfate (0.04 mg/kg, SC) and Xylazine HCL (0.01 mg/kg, IM). Anaesthesia was achieved with 12 mg/kg of Ketamine HCL, given intramuscularly, when needed.

The used exposure factors for dog's skull were 55 kVp, 10 mAs and 70 cm focal distance for open mouth ventrodorsal, intraoral and oblique nasal views; and 60 kVp for a closed mouth ventrodorsal view. For cat's skull the exposure factors were 50 kVp, 10 mAs and 70 cm focal distance (Mattoon and Drost, 2004).

The animals were subjected to the following radiographic examinations:

1- Conventional plain radiographic examination: The skull of 10 dogs and 10 cats were subjected to the following radiographic projections:

a) *Lateral radiograph*: Animals were controlled in lateral recumbency and the rostral aspect of the skull was elevated with a sponge (Fig. 1a).

b) *Dorsoventral radiograph*: Animals were placed in a crouching position. The sagittal plane was vertical and centre to the midpoint between the eyes (Fig. 1b).

c) *Rostrocaudal frontal sinus radiograph:* Animals were controlled in dorsal recumbency. The head was positioned so that the hard palate was perpendicular to the film and parallel to the central aspect of the X-ray beam (Fig. 1c).

d) *Lateral oblique radiograph:* Animals were placed in lateral recumbency with a 45 degree tilting of the head (Fig. 1d).

e) *Open-mouth ventrodorsal radiograph*: Animals were placed in dorsal recumbency with its mouth open as wide as possible. The X-ray beam was aligned 20 to 30 degrees into the oral cavity (Fig. 1e).

f) *Open-mouth lateral radiograph:* Animals were positioned like the standard lateral view except that the mouth was restrained in an open mouth position (Fig. 1f).

Open-mouth rostrocaudal radiograph: Animals were positioned in a dorsal recumbency with the maxilla taped parallel to the cassette and the mouth was held open as wide as possible (Fig. 1g).

h) *Intraoral radiograph:* Animals were placed in sternal recumbency. The corner of the film cassette was inserted as far as possible inside the mouth (Fig. 1h).

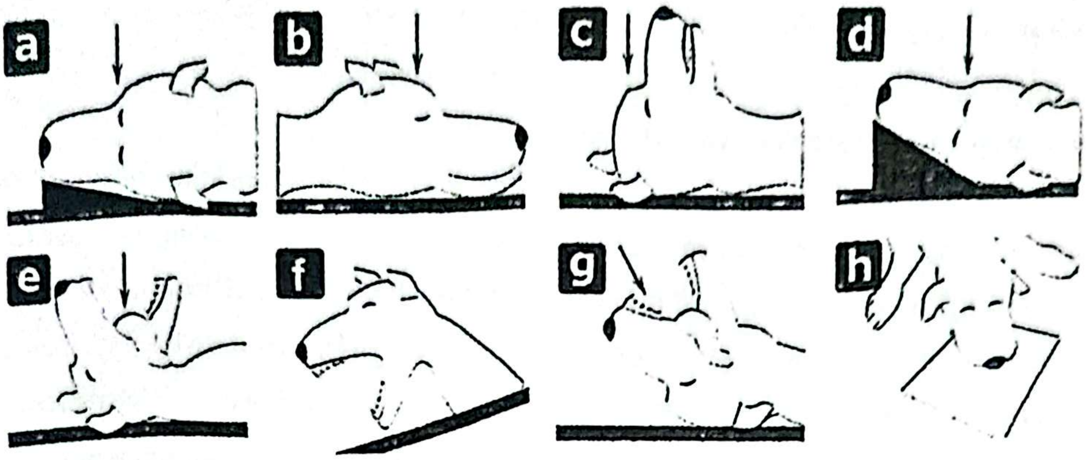


Fig. 1: Conventional plain radiographic positioning of the skull: (a) lateral (b) dorsoventral (c) rostrocaudal (d) lateral oblique (e) open-mouth ventrodorsal (f) open-mouth lateral (g) open-mouth rostrocaudal (h) Intraoral (modified after Hecht, 2003).

. Positive contrast canalographic examinaon: Canalography was performed on 20 ear caals of 10 dogs and 20 ear canals of 10 cats. Beore a canalogram was performed, the urrounding hair was removed and the ear canal as gently cleaned with saline solution. Animals ere placed on sternal recumbency. Survey radigraphs were obtained prior to canalography. Ine milliliter Urographinr® (Schering, Germay) was injected into the ear canal. The vertical ar canal was massaged for one minute to distribute the contrast medium. The ear canal was then slowly filled with contrast medium to the level of the tragus. A second massage was applied. A dorsoventral radiograph of the skull with the primary beam centered at the level of the tympanic bulla was acquired. After the canalograms were performed, the contrast medium was flushed out with saline solution. The diameter of the proximal end (nearest to tympanic bulla) of the annular cartilage was measured from the contrast images at the most depressed point between the osseous external acoustic meatus and the proximal end of the annular cartilage. The diameter of the distal end of the annular cartilage was measured at the most depressed point between the distal annular cartilage and the proximal auricular cartilage. The length of tympanic membrane was also recorded. The ratio for each canal of proximal annular versus distal annular diameter was computed for each animal and each view.

3- Positive contrast rhinographic examination:
This technique was performed on 10 dogs. A rigid endotracheal tube was used to avoid twisting during positioning. All dogs were placed in lateral recumbency with the structures of interest on the dependent side. Contrast medium (50% aqueous suspension of barium sulfate "El-Nasr for Pharmaceutical Chemicals", Egypt) was administered unilaterally intranasally with an open-end urethral catheter. The catheter was advanced along the dorsal meatus until resistance was encountered at the caudal nasal cavity; then the entire injection was made in that region. An injection of 1 ml of contrast medium per 5 kg of body weight was used. An additional contrast medium was added if inadequate filling was observed on initial radiographs. To enhance the distribution of the contrast medium within the ventral nasal cavity, a slow withdrawal of the catheter during the contrast medium administration was done (Fig. 2 A&B). Three views were obtained to evaluate the nasal cavity and frontal sinuses: a lateral, ar open-mouth ventrodorsal projection with the central radiographic beam directed caudally at a 20 angle to the ventral plane, and a rostrocaudal projection. The lateral projection was always obtained first followed by the open-mouth ventrodorsal and lateral.

The dorsal, ventral, and ethmoidal nasal concha were evaluated by advancing the catheter alon the dorsal meatus until resistance was encoun tered at the caudal nasal cavity. To enhance distri bution, the dog was placed in lateral recumben followed by ventral recumbency to evaluate t nasal concha and dorsal recumbency for fron sinus evaluation with the hard palate inclin downward at an angle of 45° to the horizon plane (Fig. 2 C&D). The ventral nasal cavity a the nasopharynx were best delineated by advar ing the catheter along the ventral meatus and i the caudoventral nasal cavity or nasophary Lateral recumbency was followed by do recumbency with the hard palate oriented ; 90° angle to the horizontal plane prior to the exposure (Fig. 2 E&F) (Robert et al, 1984).

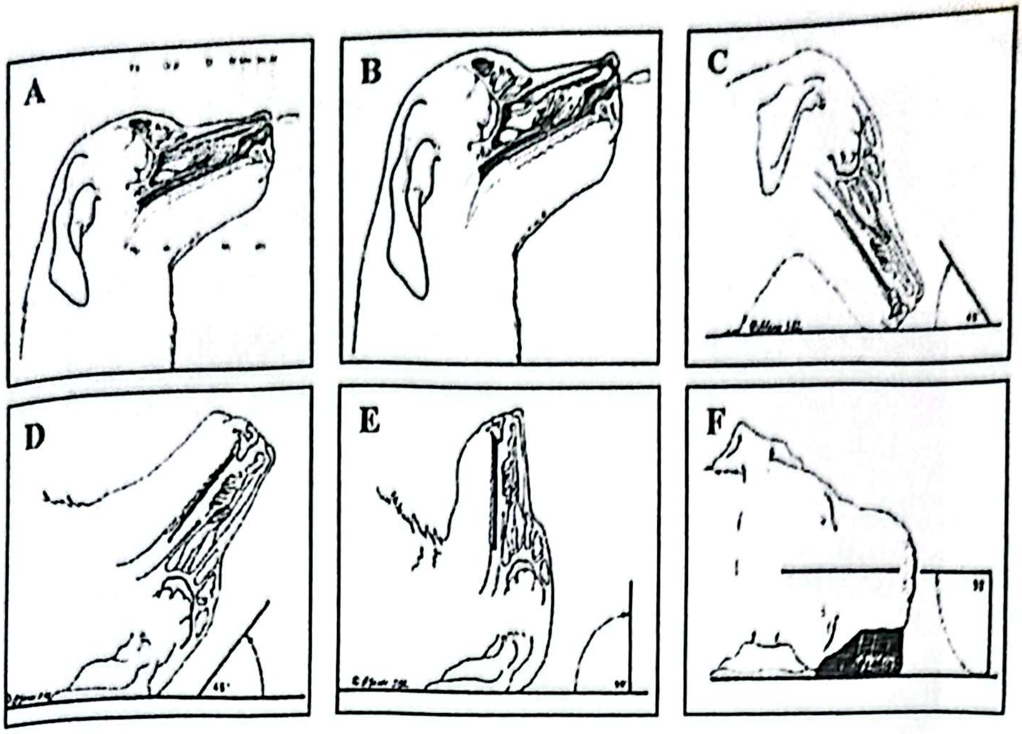
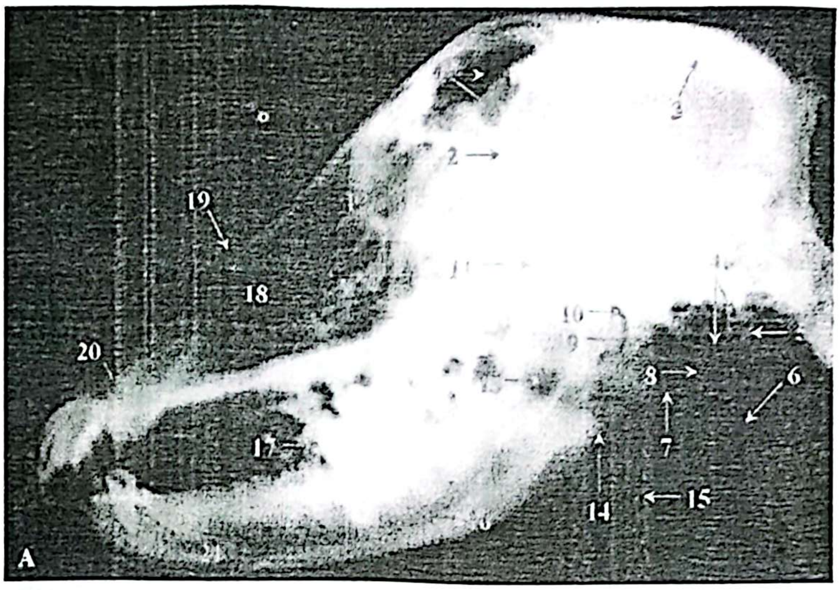


Fig. 2: Positive contrast rhinography positioning (Robert et al, 1984).

SULTS

Conventional plain radiographic findings:

The results revealed that lateral radiographs allowed a good assessment of the nasal area and the calvarium (Fig. 3 A&B).



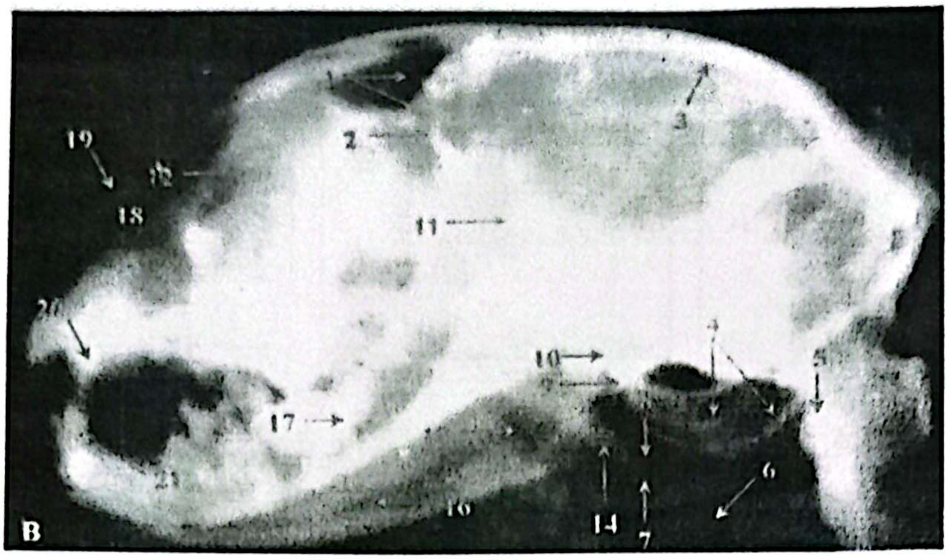


Fig. 3: Lateral radiograph of the skull of Dog (A) and Cat (B) showing: 1.Frontal sinuses 2.Calvarium 3.Sagital crest 4.Tympanic bullae 5.Paracondoyler process 6.Air within nasopharynx 7.Soft palate 8.Stylohyoid bone 9.Retroarticular process 10.Tempromandibular joint 11.Coronoid process of mandible 12.Ethmoidal conchae 13.Mandibular foramen 14.Angular process of mandible 15.Basihyoid bone 16.Mandibular canal 17.First molar 18.Nasal passage 19.Nasal bone 20.Maxillary canine teeth 21. Mandibular canine teeth.

Dorsoventral radiographs were significant for the assessment of the mandibles, calvarium, zygomatic arch and the tempromandibular joint "TMJ" (Fig. 4 A&B).

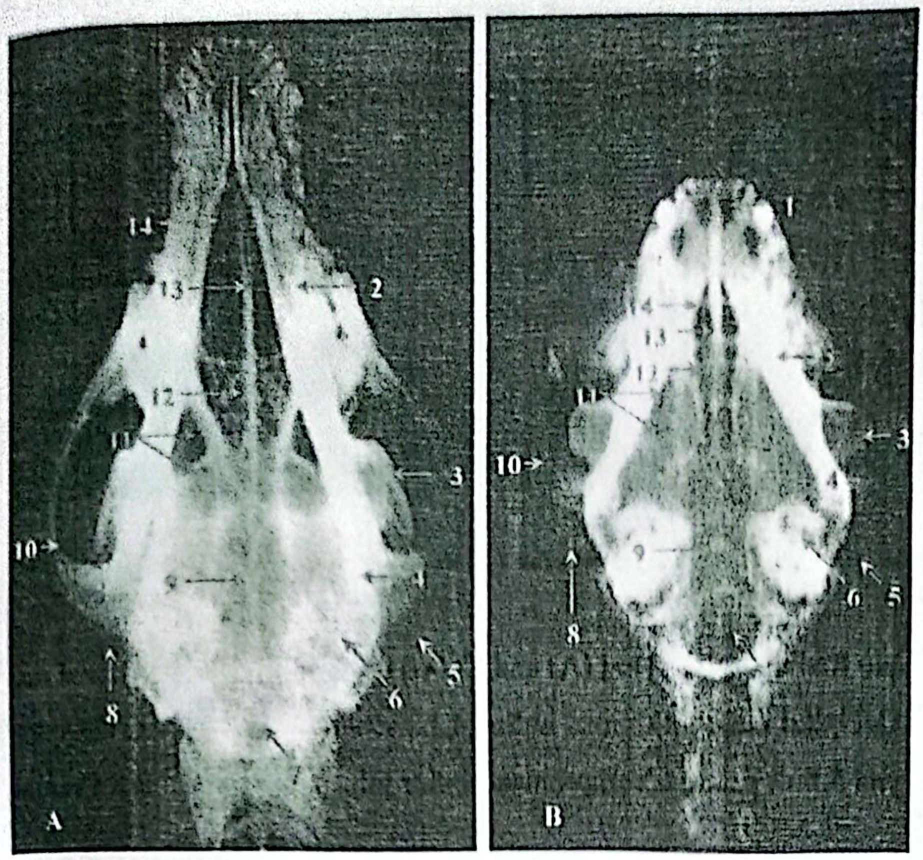


Fig. 4: Dorsoventral radiograph of Dog (A) and Cat (B) showing: 1.Palatine fissure 2.Horizontal ramus -mandible- 3.Coronoid process-mandible 4.Brain cavity 5.External acoustic meatus 6.Tympanic bulla 7.Foramen magnum 8.Air within external acoustic meatus 9.Parital crest 10.Zygomatic arch 11.Frontal sinuses 12.Ethmoidal fossa 13.Nasal septum 14.Nasal canal

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Rostrocaudal frontal radiographs were specific for the examination of the frontal sinuses, zygomatic process of the frontal bone (Fig. 5 A&B).

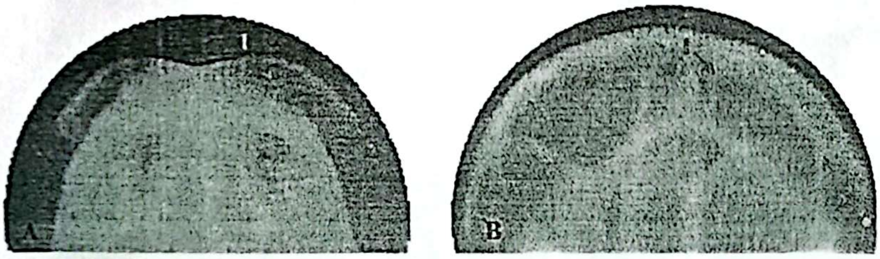


Fig. 5: Normal rostrocaudal frontal view of Dog (A) and Cat (B) skull showing 1.Frontal sinus 2.Zygomatic process of frontal bone.

The results have also shown that the lateral oblique radiographs were best for viewing the TMJ and the osseous bullae (Fig. 6 A&B).

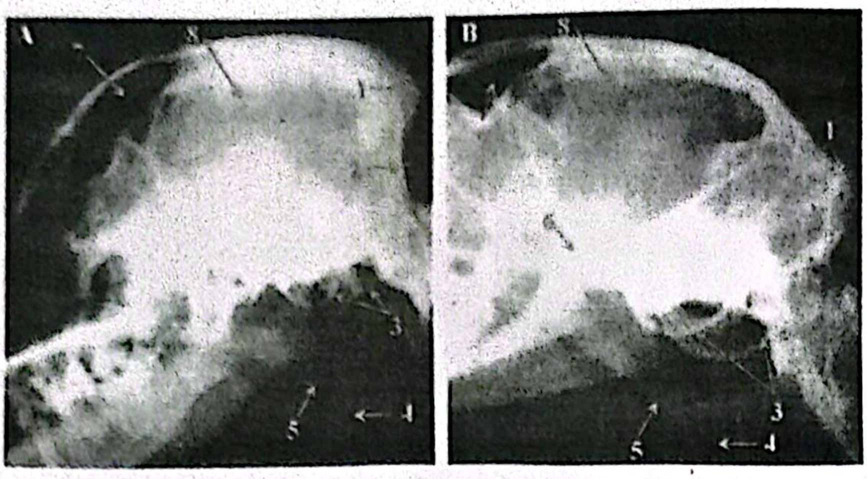


Fig. 6: Lateral oblique Radiograph of Dog (A) and Cat (B) skull showing 1.External occipital protuberance 2.Occipital bone 3.Osseous bullae 4.Junction of oropharynx, nasopharynx and laryngopharynx 5.Soft palate 6.Tempromandibular joint 7.Frontal sinus 8.Cranial cavity.

The osseous bullae were clearly examined with the open-mouth rostral radiograpihs as well (Fig. 7 A&B).

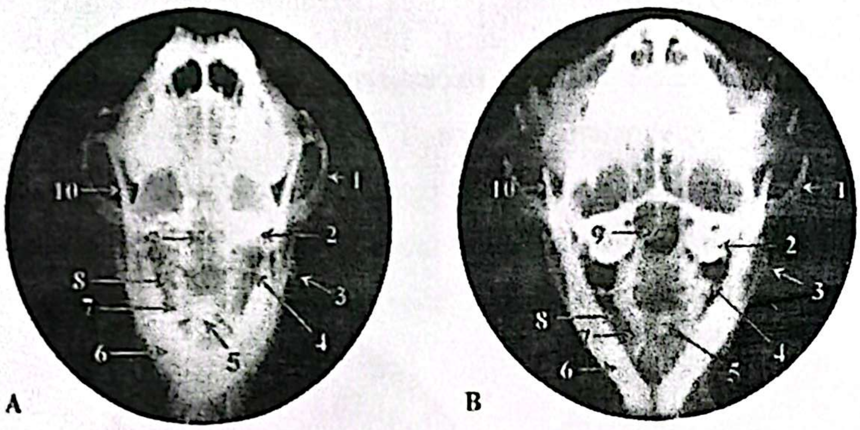
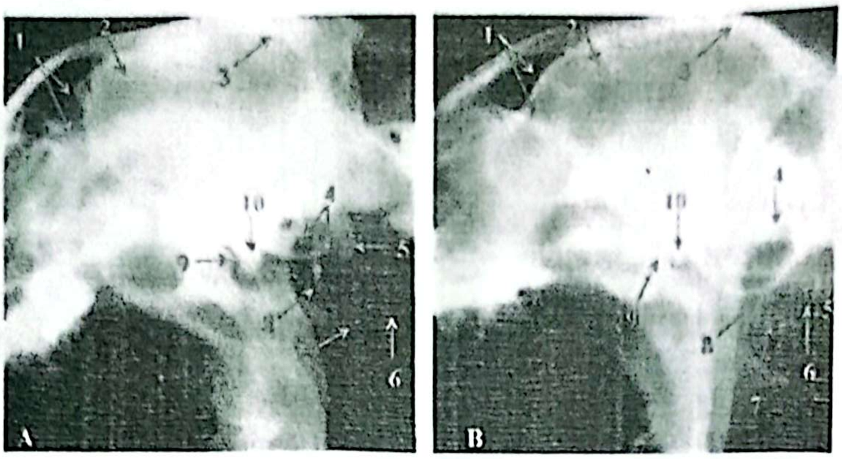


Fig. 7: Open mouth rostral radiograph of Dog (A) and Cat (B) skull showing 1.Zygomatic arch 2.Petrous temporal bone 3.Angular process of mandible 4.Tympanic bulla 5.Odontoid process of C2 6.Body of mandible 7.Wing of Atlas 8.Atlanto-occipital joint 9.Nasopharynx 10.Coronoid process of mandible.

It was found that the open-mouth lateral radiographs have made obvious the rostral portion of the -arium (Fig. 8 A&B).



-. 8: Open-mouth lateral radiograph of skull of Dog (A) and Cat (B) showing the rostral portion of the calvarium together with: 1.Frontal sinuses 2.Cranial cavity 3.Sagital crest 4.Tympanic bullae 5.Paracondoyler process 6.Air within nasopharynx 7.Soft palate 8.Stylohyoid bone 9.Tempromandibular joint 10.Retroarticular process.

Open-mouth dorsoventral radiograph was found to be a good position for viewing the nasal -vity and the frontal sinuses (Fig. 9 A&B).

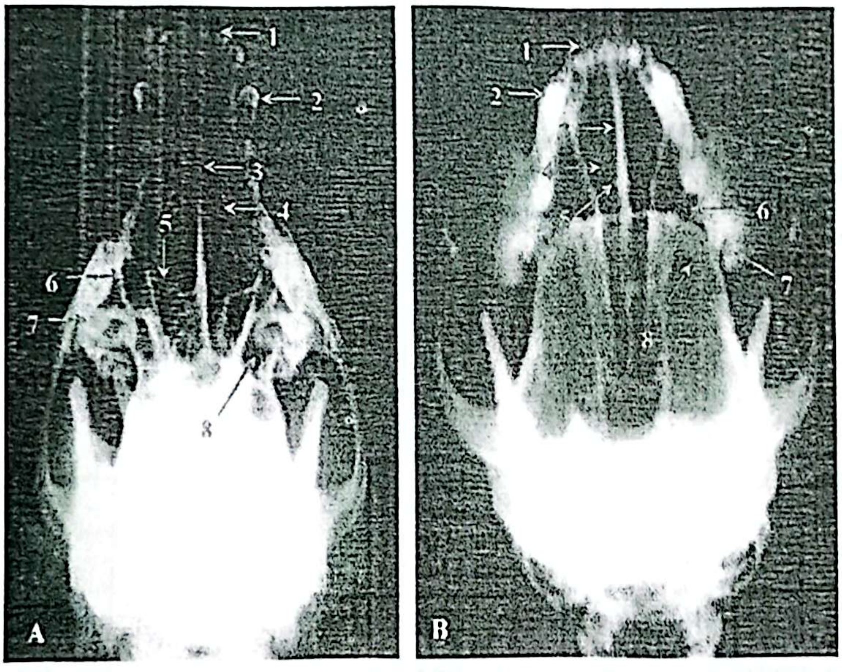


Fig. 9: Open-mouth dorsoventral radiograph of Dog (A) and Cat (B) skull showing: 1.Maxillary incisors 2.The canine tooth 3.Nasal septum 4.Nasal canal 5. Ethmoidal fossa 6.Maxillary sinus 7. First molar 8. Frontal sinus.

Intraoral radiographs clearly demonstrated the incisors teeth, canines, nasal septum, the mandibular symphysis and the horizontal ramus of the mandible (Fig. 10 A&B).

Fig. 10 (A): Maxillary radiograph of a Dog showing: 1.Incisors teeth 2.Canine tooth 3.Palatine fissure 4.Nasal septum

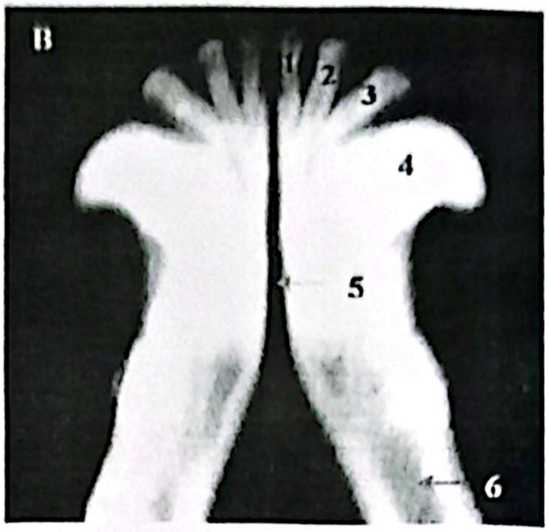


Fig. 10 (B): Mandibular radiograph of a dog showing: 1. 1st incisor, 2. 2nd incisor 3. 3rd incisor 4. Mandibular canine 5.Mandibular symphysis 6.Horizontal ramus-mandible.

2- Canalographic findings:

The results revealed that all dogs and cats tolerated canalography and did not have evidences of any problem from the contrast medium.

The measurements of the tympanic membran proximal and distal annular cartilage are listed table 1.

Table (1): Measurements of the tympanic membrane, annular and auricular cartilage of the horizontal ear canal in dorsoventral canalography in dogs & cats.

Animals	Tympanic membrane (mm ± SE)	Proximal annular cartilage (pa) (mm ± SE)	Distal annular cartilage (pa) (mm ± SE)	Mean of pa/da
Dogs	12.2 ± 4.1	5.36 ± 1.8	8 ± 2.6	0.67
Cats	9 ± 2.6	4.3 ± 1.'	5± 1.2	0.86

The external ear canal is composed of the auricular and annular cartilage. The diameter of junction formed by osseous external acoustic meatus and the annular cartilage was less than the diameter of the central portion of the annular cartilage and was visible during canalography as a circumferential indentation of the canal wall. A similar indentation was also present at the junction between the annular cartilage and the end of the auricular cartilage in the vertical ear canal. The tympanic membrane was well outlined with canalography in dogs and cats. When properly outlined by contrast medium, it appeared as an obliquely oriented line located overlying the petrosal portion of the temporal bone (Fig. 11). A ruptured tympanic membrane was recognized by the presence of contrast medium filling the tympanic bulla (Fig. 12).

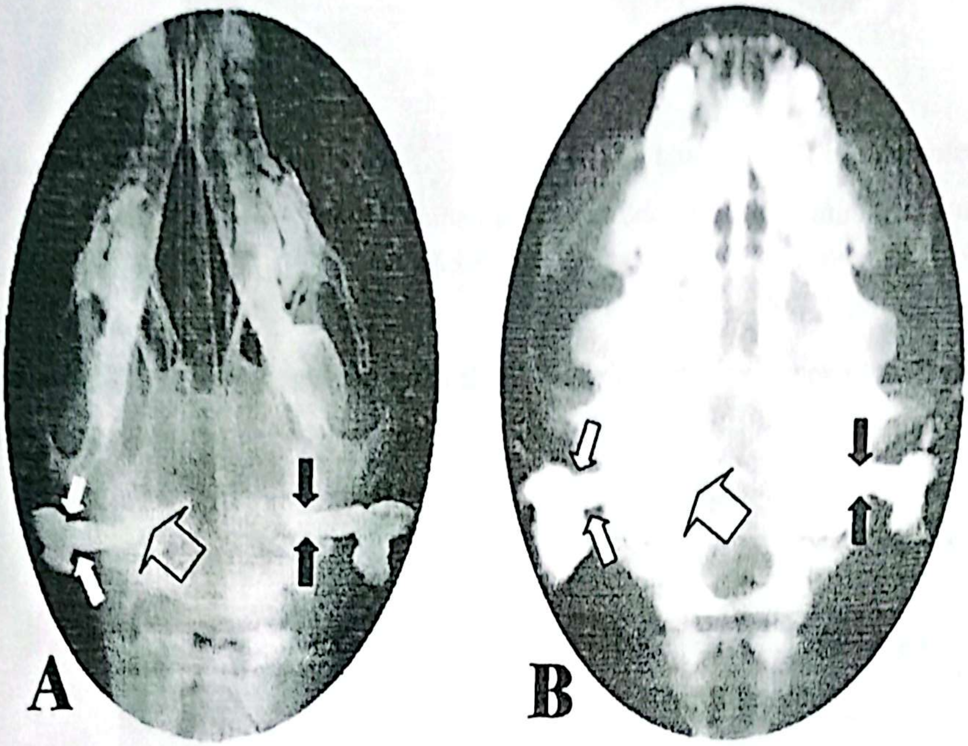


Fig. 11: Canalograph of (A) Dog Cat (B) ear with intact tympanic membrane. The proximal (black arrows) and distal (white arrows) ends of the annular cartilage appear as a slight indentation in the wall of the canal. The tympanic membrane (open arrows) overlies the petrosal portion of the temporal bone.

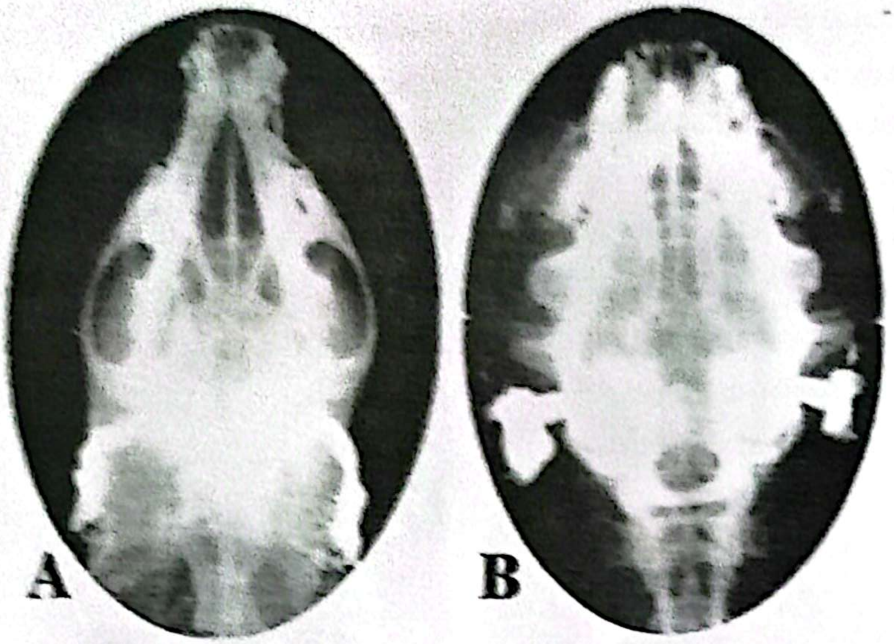
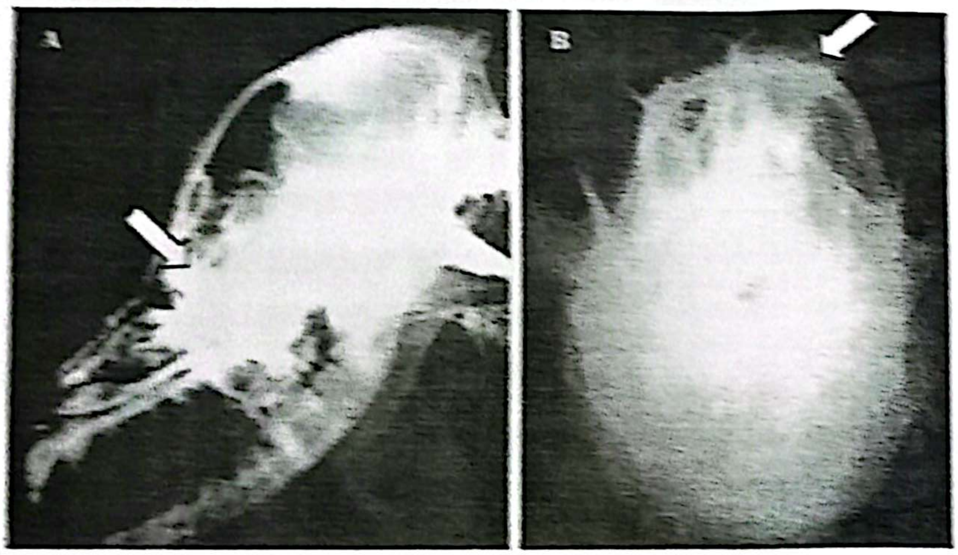


Fig. 12: Canalograph of Dog (A) and Cat (B) ear with broken tympanic membrane. Note that the contrast medium is covering the whole ear canal and tympanic bulla.

- Rhinographic findings:

he results revealed that positive contrast rhinography is a good radiographic technique for imaging the dorsal, ventral and ethmoidal nasal conchae, nasal cavity, nasopharynx and frontal sinuses (Fig. 13 A, B & C).



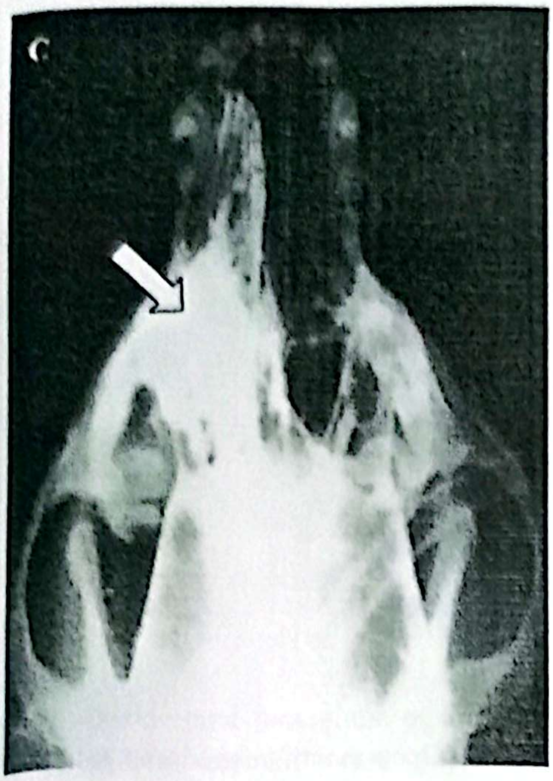


Fig. 13: Rhinographic imaging of dog's skull showing distribution of the contrast medium within the nasal conchae (A-Lateral view), in the left frontal sinus (B-Rostrocaudal view) and within the nasal conchae and frontal sinuses (C-Open-mouth ventrodorsal)

Represented clinical cases with skull affections:

The most common skull affections encountered in this study were mandibular fractures (5 cases), craniomandibular osteopathy (1 case), nasal tumors (3 cases), chronic otitis media (5 cases) and degenerative joint disease of the TMJ (1 case) as presented in the following figures:

Fig. 14: Lateral radiograph of a dog with complete comminuted fracture involving the vertical ramus of the mandible (white arrow).

Fig. 15: Lateral radiograph of a dog suffering from craniomandibular osteopathy. Note marked osteo-periostial reaction at the angle between the horizontal and vertical angle of the mandible (black arrow).

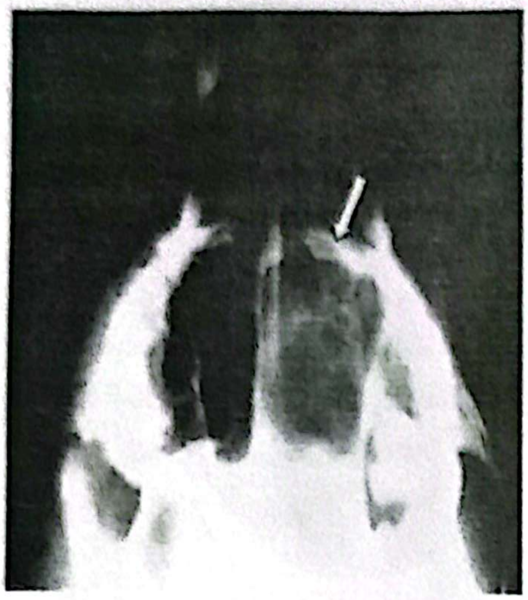


Fig. 16: Open-mouth ventrodorsal radiograph of a dog with unilateral nasal tumor with loss of nasal structures details.

Fig. 17: Open-mouth ventrodorsal radiograph of a dog with bilateral nasal tumor. Note marked loss of the nasal structures.

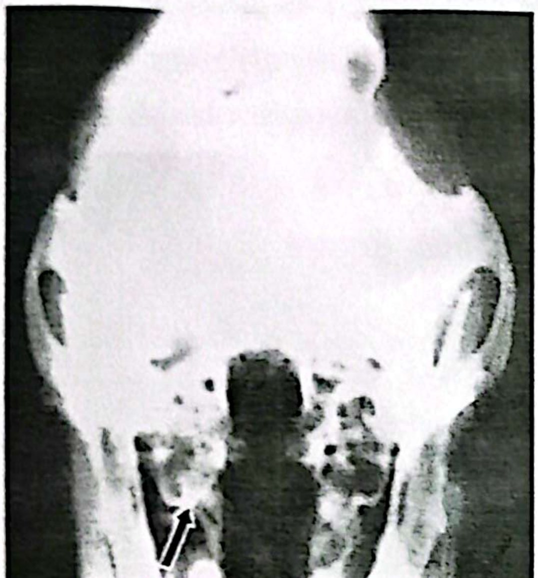


Fig. 18: Open-mouth rostrocaudal radiograph of a dog with unilateral chronic otitis media with obvious shadowing of the right osseous bulla in comparison with the normal left one (black arrow).

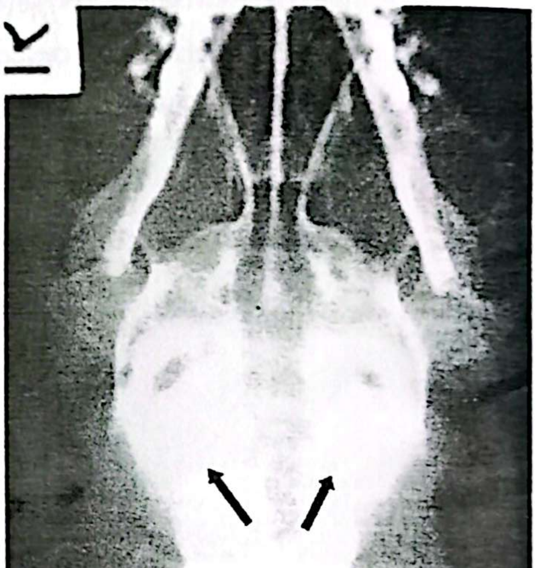


Fig. 19: Dorsoventral radiograph of a dog with bilateral chronic otitis. Note thickening of the wall and shadowing of the tympanic cavity (black arrows).

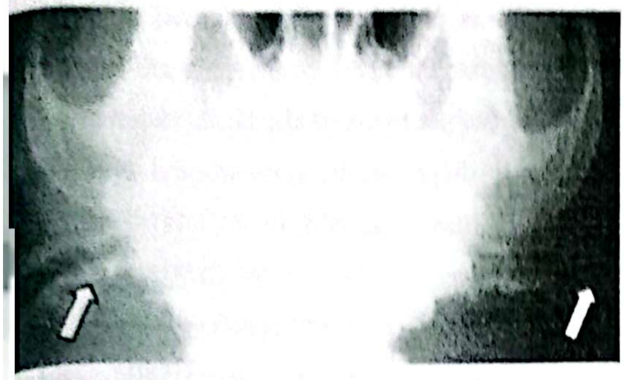


Fig. 20: Dorsoventral radiograph of a dog with bilateral chronic otitis media with marked osteosclerotic bony changes involving both osseous bullae and marked metapalsia and calcification of the horizontal ear canals (white arrows).

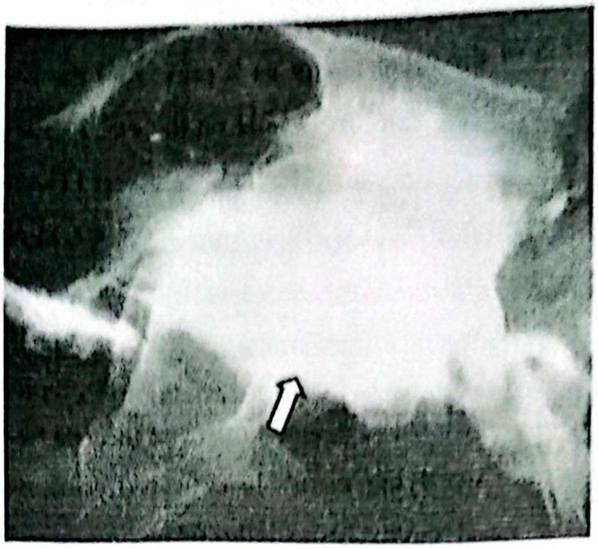


Fig. 21: Lateral radiograph of a dog with degenerative joint disease of the left tempromandibular joint (white arrow).

DISCUSSION

This study was performed to visualize the normal radiographic anatomy of the skull in dogs and cats to form a guideline for interpretation of pathological changes of the skull. As the skull is a complex structure with many overlapping shadows; multiple radiographic projections are necessary for full evaluation of patients with clinical signs that suggest involvement of the bones, sinuses, nasal passages, teeth, eyes and orbit, brain, oral cavity, ear and external soft tissues (Burk and Ackerman, 1996; Hecht, 2003 and Gioso et al, 2005).

Comparing the efficacy of the used radiographic series in evaluation of skull it was clear that an intraoral dorsoventral view of the maxilla may be used as an alternative of an open-mouth ventrodorsal projection, but it may not be possible to position the film cassette far enough into the mouth to include the entire nasal cavity. Intraoral radiographs chief limitation is that only the rostral to mid-portion of the nasal cavity can be radiographed compared with the open-mouth ventrodorsal technique which is essential to examine the caudal structures of the skull. Also, the open-mouth ventrodorsal radiographs were found to be a key to critical radiographic examination of the nasal cavity as it prevented the superimposition of the mandible on the nasal structures making it easy to view and interpret (Ticer, 1984; Bischoff and Kneller, 2004 ad Lopez, et al 2005).

Closed-mouth dorsoventral skull radiographs rarely contributed to diagnosing nasal disease because the overlying mandible obscured portions of the nasal cavity, especially when compared with an intraoral or open-mouth dorsoventral maxillary radiograph. This view is perhaps most informative when evaluating the relationship of the mandible to the maxilla (e.g. mandibular fractures, alignment, dental occlusion); mandiblular diseases, and assessing the temporomandibular joints (Burk and Ackerman, 1996; Hecht, 2003 and Gioso et al, 2005).

Oblique radiographs of the skull helped to confirm and further assess disease processes identified on the open-mouth ventrodorsal and lateral views. The lateral oblique views are especially important for assessing maxillary teeth, evaluating turbinate and maxillary and frontal bone pathology, as well as evaluating the frontal sinuses. Rostrocaudal frontal sinus radiographs allow assessment of the normal thin-walled, well-aerated frontal sinuses without interference of overlying bony structures (Mattoon and Drost, 2004 and Bischoff and Kneller, 2004).

Special radiographic projections have been described for evaluation of specific areas of the skull. These are extremely valuable and should be used when clinical signs suggest an abnormality in a specified part of the head which can not be clearly diagnosed by conventional plain radiography (Gioso et al, 2005).

The results confirmed that canalography is a useful radiographic technique to attentively examine the ear, measure the horizontal ear canal, the diameter of the proximal and distal end of the annular cartilage and to assess whether or not the tympanic membrane is ruptured prior to conservative or surgical therapy and assess the clinical relevance of the measurements in identifying abnormalities of the ear canal (Eom et al, 2000 and Dickie et al, 2003). The external ear canal, especially of the vertical one, in the dog is long and narrow measuring about 4 to 7 mm in diameter. The results of canalographic measurements showed that the diameter of the proximal and distal annular cartilage and the tympanic membrane were more or less similar to those recorded by Trower et al (1998) and Eom et al (2000). The tympanic membrane was seen as a straight or slight concave border overlying the tympanic bulla; it has a larger diameter compared with that of the distal annular cartilage. The diameter of the annular cartilage was considered to be an important factor in the evaluation of the tympanic nembrane and the horizontal ear canal. Canalog-aphy also allowed the detection of ruptured tym-anic membranes. Horizontal ear canal diameter as considered as a predictor for ear diseases and n identifying animals prone to developing ear liseases (Trower et al, 1998; Eom et al, 2000; Ki-Jong et al, 2000; and Griffiths et al, 2003).

Vith the limitations of conventional plain radiog-aphy in studying the nasal diseases, positive con-rast rhinography was found to be a good radio-graphic method to evaluate in details the nasal onchae, nasal cavity, nasopharynx and frontal si-uses. A sequence of positionings were devel-oped that maintained the contrast medium within he area of interest and avoided obscurity of the verlying contralateral structures that could ob-cure interpretation of the lateral projection of the asal cavity (Cruz-Arambulo et al, 2003). Rostro-audal nasal view was practical to build up 3-imensional image of the nasal passage patholo-y as well as detecting nasal septum and osseous asal border abnormalities which were not visible 1 other views (Kirberger and Fourie, 2002).

he most common skull affections found in this tudy were chronic otitis media, craniomandibu-ar osteopathy, degenerative joint disease of the empromandibular joint, fractures and nasal tu-nors. These were similar to the findings recorded y many authors who stated that conventional lain radiography is of a good diagnostic value or skull affections (Robert et al, 1984; Schwarz et al, 2000; Saunders et al, 2004 and Lopez et al, 2005). It was important to assess the skull for in-creased soft tissue opacity, increased radioluccn-cy, bony destruction or proliferation, deviation or destruction of the bony nasal septum and symme-try between the right and left sides of the skull. Mattoon and Drost (2004) reported that it is diffi-cult, in most instances, to differentiate a neoplas-tic process from inflammation or infection as de-struction of fine bony turbinates may occur with infection and neoplasia. Soft tissue opacity with-in the nasal cavity masks smaller, fine bony tur-binates.

In conclusion, the evaluated conventional plain radiographic positioning is a reliable method for imaging of the skull and its associated structures. Positive contrast canalography is regarded as an accurate technique to measure the diameter of the horizontal ear canal and the tympanic membrane which are counted as a predictor of ear diseases. Rhinography is most valuable in diagnosis of na-sal passage and sinuses diseases in dogs and cats.

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