RESEARCH ARTICLE

Visibility of different foreign bodies in the maxillofacial region using plain radiography, CT, MRI and ultrasonography: an *in vitro* study

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Objectives: To compare the usefulness of four imaging modalities in visualizing various foreign bodies of different sizes.

Methods: Foreign bodies of four sizes (0.5, 1, 2 and 3 mm) including metal, tooth, wood, plastic, stone, glass and graphite were embedded in six fresh sheep heads on bone surface between the corpus mandible and muscle, and inside the tongue muscle. A human dry skull served as an air-filled space. Plain radiography, CT, MRI and ultrasonography were used, and four skilled radiologists rated the findings individually.

Results: All embedded foreign bodies except wood were best visualized using CT. Wood could only be detected using ultrasonography, and then only when fragments were >0.5 mm in size. Plain radiography and CT were almost equally accurate in visualizing metal and graphite. MRI was the least useful imaging technique.

Conclusions: In cases with suspected foreign bodies in the maxillofacial region, CT seems to be the optimal initial imaging study. Wood, however, could only be detected using ultrasonography.

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Introduction

Foreign bodies offer a diagnostic challenge to the maxillofacial surgeon. About one-third of foreign bodies go unnoticed during initial examinations,¹ rendering it necessary to employ an imaging technique in suspected cases.² Using an inappropriate imaging modality, however, could result in untoward health-related consequences.^{3–5} In addition, creating an effective weighted pro–con list of foreign body removal requires

sufficient visualization and meticulous localization of the embedded fragments.^{6–8}

In general, selecting an imaging technique to optimally visualize a suspected foreign body relies upon the composition, size and location of the fragments.^{9,10}

Glass fragments, wood splinters, plastic particles and metallic objects are the most commonly encountered foreign bodies in emergency departments.¹¹ Comparatively, tooth, stone and graphite are not so frequent, but they may cause diagnostic worries if left unrecognized.^{12–16}

When a foreign object accidentally penetrates into the body, it may lodge in an air-filled space, soft tissues or

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between bones and muscles.⁹ Conventional plain radiographs, CT, ultrasonography and MRI are used routinely at trauma settings for detecting and localizing such foreign bodies.¹¹

Therefore, this study sought to compare capability of plain radiography, CT, MRI and ultrasonography in visualizing metal, tooth, wood, plastic, stone, glass and graphite foreign bodies of different sizes inside soft tissue and between bone and muscle in a sheep head model, as well as in an air-filled space.

Methods and materials

Foreign bodies

Metal (iron), tooth (both enamel and dentin), wood, plastic (polyvinyl chloride), stone, glass and graphite were used as foreign bodies (Figure 1) in this *in vitro* study. They were cut into similar shapes of 4 sizes (dimensions: 0.5, 1, 2 and 3 mm).

Specimens

Six fresh sheep heads (1 day after death) and a dry human skull were used. All imaging studies were performed on the same day. Fragments were placed at two locations in the sheep heads: (i) bone surface on the corpus mandible through a slot in the exterior covering muscle, and (ii) inside the muscle through an incision at the midline of the tongue.

A dry human skull was used as an air-filled space.

To assess false positivity, some empty slots were also made.

Imaging studies

- Conventional plain radiography: the conventional setting for imaging the human skull was used. Both anteroposterior and lateral images were taken. Exposure settings were 75 kVp and 20 mA.
- CT: Somatom® Sensation 16 CT scan machine (Siemens Healthcare, Forchheim, Germany) was used. The conventional setting for imaging the human head was used; the reconstruction matrix size, 512 × 512 pixels; kVp, 110; helical pitch, 1; gantry

rotation time, 0.37 s; resolution, 0.4 mm; increment, 0.5 mm; and slice thickness, 1 mm.

Image post processing was performed using a dedicated software package (Syngo® DynaCT Leonardo; Siemens).

- MRI: MR images were acquired using Siemens Avanto 18 Channel 1.5 T machine with a special head coil. The conventional setting for imaging the human brain was used. The sequences used consisted of *T*₁ weighted fast-spin echo (echo time, 13 ms; repetition time, 600 ms; number of excitations, 2; field of view, 16 cm; matrix, 256 × 256 pixels) and proton density/*T*₂ weighted fast-spin echo (echo time, 89 ms; repetition time, 3500 ms; number of excitations, 2; field of view, 16 cm; matrix, 256 × 192 pixels). Both sagittal and coronal planes were used with a cross-section thickness of 3 mm and spacing of 0 mm.
- Ultrasonography: ultrasound scanning was performed using an ultrasound system (Toshiba Nemio 30, 7.5 MHz linear probe for visualizing superficial tissues; Toshiba, Tokyo, Japan). This modality was not used for air-embedded fragments.

Analysis

A previously described four-point scoring scale ranging from 0 to +4¹⁴ was used for assessing the visibility of foreign bodies (Table 1). Four skilled radiologists with over 8 years’ academic experience were solicited to review and evaluate images independently. The average of the results was recorded after the observations. The observers were unaware of the composition, place or the number of embedded foreign bodies.

Results

An excellent inter-rater agreement¹⁷ was present between the observers (average Cohen’s kappa = 84%).

Visibility scores are set out in Table 2.

Metal

All metal foreign bodies were best visualized on radiographs (Figure 2) and CT images. Because of artefacts, MRI was not accurate in detecting metal. Ultrasonography

Figure 1 Materials used as foreign bodies (from left to right: plastic, tooth, graphite, wood, stone, glass and metal).

Table 1 Four-point scoring scale for image interpretation¹⁴

Score	Quality	Definition
+4	Excellent	Excellent resolution of details and excellent visibility, good demarcation from surroundings
+3	Good	Good resolution of details, demarcation from surroundings, clear visibility
+2	Fair	Insufficient resolution of details, insufficient visibility, insufficient demarcation
+1	Bad	Details not resolved, bad demarcation from surroundings, bad visibility
0	No image	Invisible

performed better than did MRI, but it was less accurate than were radiography and CT.

Tooth

CT was the best imaging technique, followed by radiography, ultrasonography and MRI, respectively.

Wood

Wood could be only detected by using ultrasonography and only when fragments were >0.5 mm in size (Figure 3).

Plastic

CT was the best imaging technique (Figure 4), followed by ultrasonography and radiography/MRI. The smallest fragments (0.5 mm) were not detected by any modality.

Stone

CT was the best imaging modality, followed by radiography, MRI (Figure 5) and ultrasonography.

Glass

CT was the most accurate imaging method, followed by radiography, ultrasonography and MRI.

Graphite

Plain radiography was the best imaging technique, followed by CT, MRI and ultrasonography.

Discussion

We compared the suitability of conventional plain radiography, CT, MRI and ultrasonography for visualizing different foreign bodies of various sizes placed in three locations.

In conformity with previous reports,^{10,14,18,19} while all metallic foreign bodies were visualized perfectly in radiographs and CT images, only large ones were detectable by ultrasound; and MRI was the least useful modality. Because of strong magnetic fields, hazardous movements may occur during MRI if metallic fragments are present within soft tissues.²⁰

Although rarely encountered as a foreign body,²¹ an undiscovered embedded tooth in the maxillofacial region may cause diagnostic problems.¹² As reported previously,¹⁰ CT was the best imaging technique for visualizing teeth, followed by radiography, ultrasound and MRI. Despite using both enamel and dentine, radiography did not perform as well as expected for radio-opaque objects in detecting teeth, possibly owing to close radio-opacities of the bone and teeth in a densely packed area such as the maxillofacial region.

Because of usually initial minor trauma^{22,23} and low visibility on plain radiographs,²⁴ missed wood foreign bodies are common. Such undiagnosed foreign bodies may cause persistent infection because they are usually dirty and carry many microorganisms.^{25,26}

On the basis of our findings, wood could be only detected using ultrasonography and only when fragments were >0.5 mm in size.

In line with this, Ginsburg *et al*²⁷ showed that superficially retained wooden foreign bodies, when not obscured by overlying gas or bone, can be most reliably visualized with ultrasonography through producing a detectable echogenic structure with acoustic shadowing. Other investigators have also suggested ultrasonography as the imaging method of choice for visualizing wooden particles embedded in soft tissues.^{14,27-31}

CT was the best imaging technique for visualizing plastic foreign bodies, only when fragments were >0.5 mm in size in the present work, followed by ultrasonography and MRI/radiography. Possibly because

Table 2 Visibility scores of foreign bodies embedded on bone surface (BS), in muscle (M) and in air (A) using radiography, CT, MRI and ultrasonography

		Materials and locations																				
		Metal			Tooth			Wood			Plastic			Stone			Glass			Graphite		
Modality	Size (mm)	BS	M	A	BS	M	A	BS	M	A	BS	M	A	BS	M	A	BS	M	A	BS	M	A
Radiography	0.5	+4	+4	+4	0	0	0	0	0	0	0	0	0	+2	0	0	0	0	0	+3	+2	+2
	1.0	+4	+4	+4	0	+1	0	0	0	0	0	0	0	+2	+1	+2	+1	0	0	+3	+3	+3
	2.0	+4	+4	+4	+1	+2	+2	0	0	0	0	0	+1	+4	+3	+3	+2	+1	+2	+3	+3	+3
	3.0	+4	+4	+4	+2	+3	+3	0	0	0	+1	+1	+2	+4	+3	+3	+2	+2	+3	+4	+4	+4
CT	0.5	+4	+4	+4	+1	+1	+2	0	0	0	0	0	0	+3	+3	+3	+3	+2	+4	+1	+2	+1
	1.0	+4	+4	+4	+3	+4	+4	0	0	0	+1	+2	+2	+4	+4	+3	+3	+4	+4	+3	+3	+3
	2.0	+4	+4	+4	+4	+4	+4	0	0	0	+3	+3	+4	+4	+4	+4	+4	+4	+4	+4	+4	+4
	3.0	+4	+4	+4	+4	+4	+4	0	0	0	+4	+4	+4	+4	+4	+4	+4	+4	+4	+4	+4	+4
MRI	0.5	+1	+1	NU	0	0	0	0	0	0	0	0	0	+3	+3	0	0	0	0	+3	+3	0
	1.0	+1	+1	NU	0	+2	0	0	0	0	0	0	0	+3	+3	0	0	0	0	+3	+3	0
	2.0	+1	+1	NU	+1	+2	0	0	0	0	+2	0	0	+3	+3	0	+1	+2	0	+3	+3	0
	3.0	0	0	NU	+1	+3	0	0	0	0	+2	+2	0	+4	+3	0	+2	+2	0	+4	+3	0
Ultrasound	0.5	0	0	NU	0	0	NU	0	0	NU	0	0	NU	0	0	NU	0	0	NU	0	0	NU
	1.0	0	0	NU	0	0	NU	+1	+1	NU	0	0	NU	0	0	NU	0	0	NU	0	0	NU
	2.0	+3	+3	NU	+3	+3	NU	+4	+4	NU	+3	+3	NU	+3	+3	NU	+3	+3	NU	+3	+3	NU
	3.0	+3	+4	NU	+3	+3	NU	+4	+4	NU	+3	+3	NU	+3	+4	NU	+3	+3	NU	+3	+3	NU

NU, not used.

Figure 2 Visibility of metal (size, 3 mm) on the bone surface using radiography. Arrow indicates foreign body.

of using different types and sizes of plastic fragments, reports are discordant in this regard.^{14,27,28,32} For example, while CT and ultrasound were similarly accurate in detecting large plastic fragments, for smaller foreign

Figure 3 Visibility of wood (size, 2 mm) inside the muscle using ultrasonography. Arrow indicates foreign body.

Figure 4 Visibility of plastic (size, 2 mm) in the air using CT. Arrow indicates foreign body.

bodies, for example, 1 mm in size, the latter proved useless.

Hyperechoic areas with posterior shadows and reverberation artefacts are essential for detecting foreign bodies by ultrasound.³³ When foreign bodies are small, however, these clues may disappear or become overlooked.¹⁹

Visibilities of stone and metallic foreign bodies were similar in this study; a finding in line with the results of a previous study.¹⁴

In conformity with previous reports,^{14,27,32} CT was the most accurate method for detecting glass, followed by radiography, MRI and ultrasound, respectively.

Penetrating pencil-tip injuries are frequent among children, and the embedded graphite core may increase morbidity or may lead to misdiagnosis.^{15,16} As reported in another study,³⁴ CT was the best imaging modality to detect graphite in the present work.

Figure 5 Visibility of stone (size, 1 mm) inside the muscle using MRI. Arrow indicates foreign body.

In cases with suspected foreign bodies, conventional plain radiography is usually the initial imaging technique.²⁰ It is widely available, simple and sufficiently accurate in detecting radio-opaque objects, but it may fall short, as shown in the present work, of the goal of identifying radiolucent objects or defining their precise localization.³⁵

CT is more accurate,⁹ particularly when a non-opaque object is anticipated¹¹ or the foreign body is located inside pneumatized areas.¹⁴

MRI is sophisticated, expensive and not widely available. This modality cannot be used initially in cases with suspected foreign body with unknown composition. In addition, artefacts could compromise clear visualization of metal, glass, graphite and even plastic.^{10,36}

Ultrasonography causes no radiation exposure, is inexpensive, provides real-time imaging and is available widely even at bedside.^{37,38}

In the case of superficial, non-opaque foreign bodies,¹¹ ultrasonography is highly sensitive.³⁸ To detect deeply embedded foreign bodies high frequency ultrasonography may be more accurate than the conventional low-frequency (3.5–5.0 MHz) technique.³⁹ It should be noted that, however, low-frequency transducers are more available than high-frequency transducers in emergency departments.²⁸

Owing to a reason that needs no further explanation, this study was not an *in vivo* examination.

In vitro models lack the ability to reproduce inflammatory reactions around foreign bodies. So, contrast media cannot be used; the influence of body reaction on image quality in chronic cases cannot be appreciated;⁴⁰ and the tissue swelling around an embedded foreign body as an indirect clue for its presence is missing.¹

Because of limited room inside the maxillofacial sinuses, a dry human skull served as an air-filled space in the present work. The use of a dry human skull without wet soft tissues, however, may seem irrelevant to the clinical application; a limitation that should be acknowledged.

Finally, several parameters such as Hounsfield units, acoustic properties, water content and relaxation time may be helpful for better interpretation of results in future studies.

Conclusion

CT was the method of choice in visualizing metal, tooth, plastic, stone, glass and graphite foreign bodies in the maxillofacial region. Plain radiography could be considered as the method of second choice in visualizing metal, tooth, stone, glass and graphite. Wood could only be detected using ultrasonography, and then only when fragments were >0.5 mm in size.

References

- Krimmel M, Cornelius CP, Stojadinovic S, Hoffmann J, Reinert S. Wooden foreign bodies in facial injury: a radiological pitfall. *Int J Oral Maxillofac Surg* 2001; **30**: 445–7.
- Rudagi BM, Halli R, Kini Y, Kharkhar V, Saluja H. Foreign bodies in facial trauma-report of 3 cases. *J Maxillofac Oral Surg* 2013; **12**: 210–13. doi: [10.1007/s12663-010-0072-1](https://doi.org/10.1007/s12663-010-0072-1)
- Kempf L, Braun KF, Neu J. Foreign body retention after soft tissue laceration. A case of insufficient inspection and documentation. [In German.] *Unfallchirurg* 2014; **117**: 162–6. doi: [10.1007/s00113-013-2535-6](https://doi.org/10.1007/s00113-013-2535-6)
- Swathi N, Umadevi J. An undetected intraorbital foreign body after a “trivial” facial injury. *J Craniofac Surg* 2014; **25**: 1782–3. doi: [10.1097/SCS.0b013e31821cc53e](https://doi.org/10.1097/SCS.0b013e31821cc53e)
- Santos Tde S, Melo AR, de Moraes HH, Avelar RL, Becker OE, Haas OL Jr, et al. Impacted foreign bodies in the maxillofacial region-diagnosis and treatment. *J Craniofac Surg* 2011; **22**: 1404–8. doi: [10.1097/SCS.0b013e31821cc53e](https://doi.org/10.1097/SCS.0b013e31821cc53e)
- Bede SY, Ahmed FT. Management of retained foreign bodies in missile injuries of the maxillofacial region. *J Craniofac Surg* 2011; **22**: 1440–4. doi: [10.1097/SCS.0b013e31821d17ee](https://doi.org/10.1097/SCS.0b013e31821d17ee)
- Martins WD, Favaro DM, Westphalen FH. Emergency maxillofacial radiology. Foreign body localization: report of cases. *Dentomaxillofac Radiol* 2005; **34**: 189–92.
- Faguy K. Imaging foreign bodies. *Radiol Technol* 2014; **85**: 655–78.
- Eggers G, Mukhamadiev D, Hassfeld S. Detection of foreign bodies of the head with digital volume tomography. *Dentomaxillofac Radiol* 2005; **34**: 74–9.
- Oikarinen KS, Nieminen TM, Makarainen H, Pyhtinen J. Visibility of foreign bodies in soft tissue in plain radiographs, computed tomography, magnetic resonance imaging, and ultrasound. An *in vitro* study. *Int J Oral Maxillofac Surg* 1993; **22**: 119–24.
- Hunter TB, Taljanovic MS. Foreign bodies. *Radiographics* 2003; **23**: 731–57.
- Lauritano D, Petrucci M, Sacco G, Campus G, Carinci F, Milillo L. Dental fragment embedded in the lower lip after facial trauma: brief review literature and report of a case. *Dent Res J (Isfahan)* 2012; **9**: S237–41. doi: [10.4103/1735-3327.109769](https://doi.org/10.4103/1735-3327.109769)
- Maizlin ZV, Vos PM, Lee A, Syed NS, Anaspure RS, Mah JY, et al. Stone foreign body—radiographic and CT appearance. *Emerg Radiol* 2012; **19**: 317–22. doi: [10.1007/s10140-012-1031-6](https://doi.org/10.1007/s10140-012-1031-6)
- Aras MH, Miloglu O, Barutcuoglu C, Kantarci M, Ozcan E, Hararli A. Comparison of the sensitivity for detecting foreign bodies among conventional plain radiography, computed tomography and ultrasonography. *Dentomaxillofac Radiol* 2010; **39**: 72–8. doi: [10.1259/dmfr/68589458](https://doi.org/10.1259/dmfr/68589458)
- Seitz IA, Silva BA, Schechter LS. Unusual sequela from a pencil stab wound reveals a retained graphite foreign body. *Pediatr Emerg Care* 2014; **30**: 568–70. doi: [10.1097/PEC.0000000000000192](https://doi.org/10.1097/PEC.0000000000000192)
- Gul A, Can E, Yücel OE, Niyaz L, Akgun HI, Aritürk N. Suspected endothelial pencil graphite deposition. *Case Rep Ophthalmol Med* 2013; **2013**: 369374. doi: [10.1155/2013/369374](https://doi.org/10.1155/2013/369374)
- Pouriesa M, Fouladi RF, Mesbahi S. Disproportion of end plates and the lumbar intervertebral disc herniation. *Spine J* 2013; **13**: 402–7. doi: [10.1016/j.spinee.2012.11.047](https://doi.org/10.1016/j.spinee.2012.11.047)
- Manthey DE, Storrow AB, Milbourn JM, Wagner BJ. Ultrasound versus radiography in the detection of soft-tissue foreign bodies. *Ann Emerg Med* 1996; **28**: 7–9.
- Crystal CS, Masneri DA, Hellums JS, Kaylor DW, Young SE, Miller MA, et al. Bedside ultrasound for the detection of soft tissue foreign bodies: a cadaveric study. *J Emerg Med* 2009; **36**: 377–80. doi: [10.1016/j.jemermed.2007.10.071](https://doi.org/10.1016/j.jemermed.2007.10.071)
- Stockmann P, Vairaktaris E, Fenner M, Tudor C, Neukam FW, Nkenke E. Conventional radiographs: are they still the standard

- in localization of projectiles? *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007; **104**: e71–5.
21. Leith R, O'Connell AC. A foreign body in disguise. *Eur Arch Paediatr Dent* 2013; **14**: 359–62. doi: [10.1007/s40368-013-0060-5](https://doi.org/10.1007/s40368-013-0060-5)
 22. Robinson PD, Rajayogeswaran V, Orr R. Unlikely foreign bodies in unusual facial sites. *Br J Oral Maxillofac Surg* 1997; **35**: 36–9.
 23. van der Wal KG, Boukes RJ. Intraorbital bamboo foreign body in a chronic stage: case report. *Int J Oral Maxillofac Surg* 2000; **29**: 428–9.
 24. Anderson MA, Newmeyer WL III, Kilgore ES Jr. Diagnosis and treatment of retained foreign bodies in the hand. *Am J Surg* 1982; **144**: 63–7.
 25. Vikram A, Mowar A, Kumar S. Wooden foreign body embedded in the zygomatic region for 2 years. *J Maxillofac Oral Surg* 2012; **11**: 96–100. doi: [10.1007/s12663-010-0161-1](https://doi.org/10.1007/s12663-010-0161-1)
 26. Specht CS, Varga JH, Jalali MM, Edelstein JP. Orbitocranial wooden foreign body diagnosed by magnetic resonance imaging. Dry wood can be isodense with air and orbital fat by computed tomography. *Surv Ophthalmol* 1992; **36**: 341–4.
 27. Ginsburg MJ, Ellis GL, Flom LL. Detection of soft-tissue foreign bodies by plain radiography, xerography, computed tomography, and ultrasonography. *Ann Emerg Med* 1990; **19**: 701–3.
 28. Hill R, Conron R, Greissinger P, Heller M. Ultrasound for the detection of foreign bodies in human tissue. *Ann Emerg Med* 1997; **29**: 353–6.
 29. Graham DD Jr. Ultrasound in the emergency department: detection of wooden foreign bodies in the soft tissues. *J Emerg Med* 2002; **22**: 75–9.
 30. Venter NG, Jamel N, Marques RG, Djahjah F, Mendonca Lde S. Evaluation of radiological methods for detection of wood foreign body in animal model. [In Portuguese.] *Acta Cir Bras* 2005; **20** (Suppl. 1): 34–41.
 31. Peterson JJ, Bancroft LW, Kransdorf MJ. Wooden foreign bodies: imaging appearance. *AJR Am J Roentgenol* 2002; **178**: 557–62.
 32. Pattamapaspong N, Srisuwan T, Sivasomboon C, Nasuto M, Suwannahoy P, Settakorn J, et al. Accuracy of radiography, computed tomography and magnetic resonance imaging in diagnosing foreign bodies in the foot. *Radiol Med* 2013; **118**: 303–10. doi: [10.1007/s11547-012-0844-4](https://doi.org/10.1007/s11547-012-0844-4)
 33. Abu-Zidan FM, Hefny AF, Corr P. Clinical ultrasound physics. *J Emerg Trauma Shock* 2011; **4**: 501–3. doi: [10.4103/0974-2700.86646](https://doi.org/10.4103/0974-2700.86646)
 34. Choudhri AF, Patel BJ, Phillips ME, Mills KA, Whitehead MT, Fleming JC. Diamagnetic susceptibility artifact associated with graphite foreign body of the orbit. *Ophthalm Plast Reconstr Surg* 2013; **29**: e105–7. doi: [10.1097/IOP.0b013e31827df017](https://doi.org/10.1097/IOP.0b013e31827df017)
 35. Eggers G, Welzel T, Mukhamadiev D, Wörtche R, Hassfeld S, Mühling J. X-ray-based volumetric imaging of foreign bodies: a comparison of computed tomography and digital volume tomography. *J Oral Maxillofac Surg* 2007; **65**: 1880–5.
 36. Lagalla R, Manfrè L, Caronia A, Bencivinni F, Duranti C, Ponte F. Plain film, CT and MRI sensibility in the evaluation of intra-orbital foreign bodies in an *in vitro* model of the orbit and in pig eyes. *Eur Radiol* 2000; **10**: 1338–41.
 37. Orlinsky M, Knittel P, Feit T, Chan L, Mandavia D. The comparative accuracy of radiolucent foreign body detection using ultrasonography. *Am J Emerg Med* 2000; **18**: 401–3.
 38. Jacobson JA, Powell A, Craig JG, Bouffard JA, van Holsbeeck MT. Wooden foreign bodies in soft tissue: detection at US. *Radiology* 1998; **206**: 45–8.
 39. Turkcuer I, Atilla R, Topacoglu H, Yanturali S, Kiyan S, Kabakci N, et al. Do we really need plain and soft-tissue radiographies to detect radiolucent foreign bodies in the ED? *Am J Emerg Med* 2006; **24**: 763–8.
 40. Ober CP, Jones JC, Larson MM, Lanz OI, Werre SR. Comparison of ultrasound, computed tomography, and magnetic resonance imaging in detection of acute wooden foreign bodies in the canine manus. *Vet Radiol Ultrasound* 2008; **49**: 411–18.