Dentomaxillofacial Radiology (2010) 39, 72–78

http://dmfr.birjournals.org

RESEARCH

Comparison of the sensitivity for detecting foreign bodies among conventional plain radiography, computed tomography and ultrasonography

MH Aras[1], O Miloglu*[,2], C Barutcugil[3], M Kantarci[4], E Ozcan[5] and A Harorli[2]

[1]Department of Oral and Maxillofacial Surgery, Faculty of Dentistry, Gaziantep University, Gaziantep, Turkey; [2]Department of Oral Diagnosis and Radiology, Faculty of Dentistry, Ataturk University, Erzurum, Turkey; [3]Department of Conservative Dentistry, Faculty of Dentistry, Ataturk University, Erzurum, Turkey; [4]Department of Radiology, Faculty of Medicine, Ataturk University, Erzurum, Turkey; [5]Department of Endodontics, Faculty of Dentistry, Ataturk University, Erzurum, Turkey

Objective: The purpose of this study was to compare the sensitivity for detecting foreign bodies among conventional plain radiography, CT and ultrasonography in *in vitro* models.
Methods: Seven different materials were selected as foreign bodies with dimensions of approximately $1 \times 1 \times 0.1$ cm. These materials were metal, glass, wood, stone, acrylic, graphite and Bakelite. These foreign bodies were placed into a sheep's head between the corpus mandible and muscle, in the tongue and in the maxillary sinus. Conventional plain radiography, CT and ultrasonography imaging methods were compared to investigate their sensitivity for detecting these foreign bodies.
Results: Metal, glass and stone can be detected with all the visualization techniques used in the study in all of the zones. In contrast to this, foreign bodies with low radiopacity, which could be detected in air with CT, became less visible or almost invisible in muscle tissue and between bone and muscle tissue. The performance of ultrasonography for visualizing foreign bodies with low radiopacity is relatively better than CT.
Conclusions: Ultrasonography detects and localizes superficial foreign bodies with low radiopacity in the tissues of the body more effectively than CT and conventional plain radiography. However, CT is a more effective technique for visualization of foreign bodies in air than ultrasound and conventional plain radiography.
Dentomaxillofacial Radiology (2010) **39,** 72–78. doi: 10.1259/dmfr/68589458

Keywords: computerized tomography; foreign body; plain radiography; ultrasonography

Introduction

Foreign bodies are any objects originating outside the body. They frequently occur due to various accidental injuries such as traffic accidents, explosions or bursts, and gunshot injuries in the maxillofacial region. Depending on the type of trauma, the composition and location of the foreign bodies can vary considerably.[1] Infection, inflammation and pain are potential complications after impact of foreign bodies. Superficial foreign bodies are usually easy to remove if seen. However, penetrating foreign bodies are more difficult to remove. It is necessary to determine whether the foreign body is near a vital structure or not. The most common retained objects are wood splinters, glass fragments and metallic objects.[2] Localizing and retrieving foreign bodies can be complicated. Conventional plain radiographs, CT, ultrasonography and MRI can be used to identify foreign bodies.[2]

The purpose of this study is to investigate the sensitivity of conventional plain radiography, CT and ultrasonography for detecting foreign bodies in *in vitro* models.

Materials and methods

Foreign bodies

Seven different materials were prepared as foreign bodies with dimensions of about $1 \times 1 \times 0.1$ cm for this

*Correspondence to: Dr Ozkan Miloglu, Department of Oral Diagnosis and Radiology, Faculty of Dentistry, Ataturk University, Erzurum, 25240, Turkey; E-mail: omiloglu@hotmail.com
Received 9 December 2008; revised 30 January 2009; accepted 5 April 2009

Table 1 Radiopacity of the investigated foreign bodies and their surroundings

	HU
Metal	3863–15363
Glass	540–1740
Wood	50–80
Stone	2200–2900
Acrylic	80–130
Graphite	750–1036
Bakelite	85–170
Bone	80–110
Muscle	55–65
Air	−1024

in vitro study. The most frequently retained foreign body materials were selected as metal (made up of iron), glass, wood, stone, acrylic, graphite and Bakelite. As a benchmark for the substances' radiopacity, the foreign bodies were scanned using a spiral CT scanner. Radiopacities of substances and surrounding areas were measured in HU (Table 1).

Specimen (sheep's head): Only one specimen (sheep's head) was used in this study. The applications on the specimen were done 1 day after death. All of the images were taken in the same day.

Foreign bodies on bone surface: Foreign bodies were placed between the corpus mandible and muscle in a sheep's head. With a scalpel, a slot was prepared in the muscle and the foreign body was placed vertically onto the bone's surface.

Foreign bodies in muscular tissue: Foreign bodies were placed into the sheep's tongue. With a scalpel, a tunnelling gap was prepared in the tongue and the foreign body was placed horizontally in the middle of the sheep's tongue.

Foreign bodies in air: Foreign bodies were placed into the maxillary sinus of the sheep's head. With a sharp osteotome, a triangular window was opened in the crestal ridge of the maxilla and the foreign body was placed directly into the sinus. The window was closed before imaging.

Imaging

Three different imaging methods were compared to investigate their sensitivity for detecting foreign bodies in the *in vitro* models.

Conventional plain radiography: Conventional plain film imaging was performed using the lateral cephalometric mode of a Planmeca Proline CC 2002 (Helsinki, Finland). Lateral cephalometric radiography has been used for monitoring unknown objects. An apparatus was used to position the specimen with the mid-sagittal plane vertical and Frankfurt plane horizontal. Exposure settings were 65 kVp, 2 mA and 0.8 s.

CT: Multidetector spiral CT was performed with a 16 detector-row CT scanner (Aquillon; Toshiba Medical Systems, Tokyo, Japan). Scans were obtained by using a collimation of 1 mm, 16 rows, with a helical pitch of 3, a gantry rotation speed of 0.75 s per round, voltage of 120 kV and current of 300 mA.

To ensure standardization in all imaging techniques, the sheep's head was fixed during scanning and was not moved while changing foreign bodies.

Ultrasonography

Ultrasound scanning was performed using an ultrasound system (Toshiba Aplio SSA-770A, 7.5 MHz linear probe for visualizing superficial tissues; Toshiba, Tokyo, Japan). The ultrasound probe was placed to obtain images of the dorsal aspect of the tongue. Scanning parameters were obtained by one of the authors, a radiology specialist with 10 years' experience (MK), at Ataturk University, Faculty of Medicine and Department of Radiology, on a real-time basis.

Analysis

The imaging methods were investigated to assess each foreign body's visibility on a four-point scale with the anchors "no image" (0) and "excellent image" (4+) (Table 2). The images were independently assessed by six different observers, three of whom were qualified to PhD level (one maxillofacial surgeon and two radiologists) and three research assistants (one studying oral diagnosis and radiology, one studying endodontics and one studying conservative dentistry). The observers were aware of the existence of the foreign bodies; however, they were not aware of the composition of the foreign bodies. The average of the results was recorded after the observations.

Results

Conventional lateral plain radiography

Table 3 summarises the visibility of the foreign bodies in conventional plain radiographs. The conventional plain radiography images showed no artefacts. Metal,

Table 2 Basic criteria used for image interpretation

Grade	*Assessment*	*Definition*
++++	Excellent image	Excellent resolution of details and excellent visibility, good demarcation from surrounding
+++	Good image	Good resolution of details, demarcation from surrounding, clear visibility
++	Fair image	Insufficient resolution of details, insufficient visibility, insufficient demarcation
+	Bad image	Details not resolved, bad demarcation from surrounding, bad visibility
0	No image	Invisible

Table 3 Image quality of foreign bodies in various regions observed *via* conventional plain radiography

Conventional plain	*Visibility on bone*	*Visibility in muscle*	*Visibility in air*
Metal	++++	+++	+++
Glass	++	++	++
Wood	0	0	0
Stone	+++	++	+++
Acrylic	0	0	0
Graphite	0	++	0
Bakelite	0	0	0

glass and stone foreign bodies were clearly detected between bone and muscle, whereas wood, acrylic, graphite and Bakelite were not detected at all. Metal, glass, stone and graphite foreign bodies were clearly detected in the muscle, whereas wood, acrylic and Bakelite were not detected at all. Metal, glass and stone foreign bodies were clearly detected in the maxillary sinus, whereas wood, acrylic, graphite and Bakelite were not detected at all (Figures 1a, 2a and 3a).

CT

Table 4 summarises the visibility of the foreign bodies in the CT images. The image of the metallic foreign

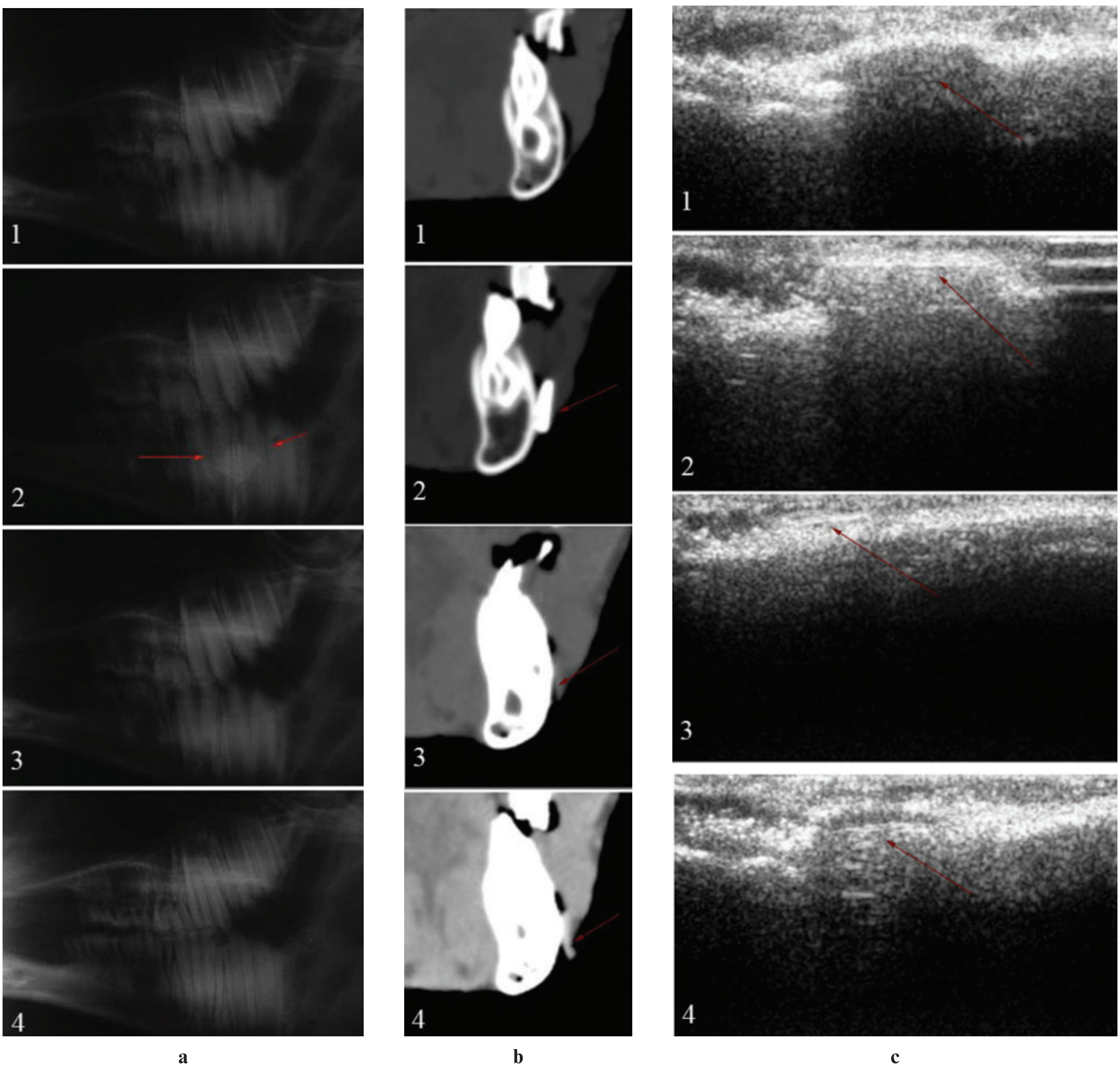


Figure 1 Visibility of foreign body on bone. (a) Conventional plain radiography. (b) CT. (c) Ultrasonography. 1, dry wood; 2, stone; 3, acrylic; 4, Bakelite

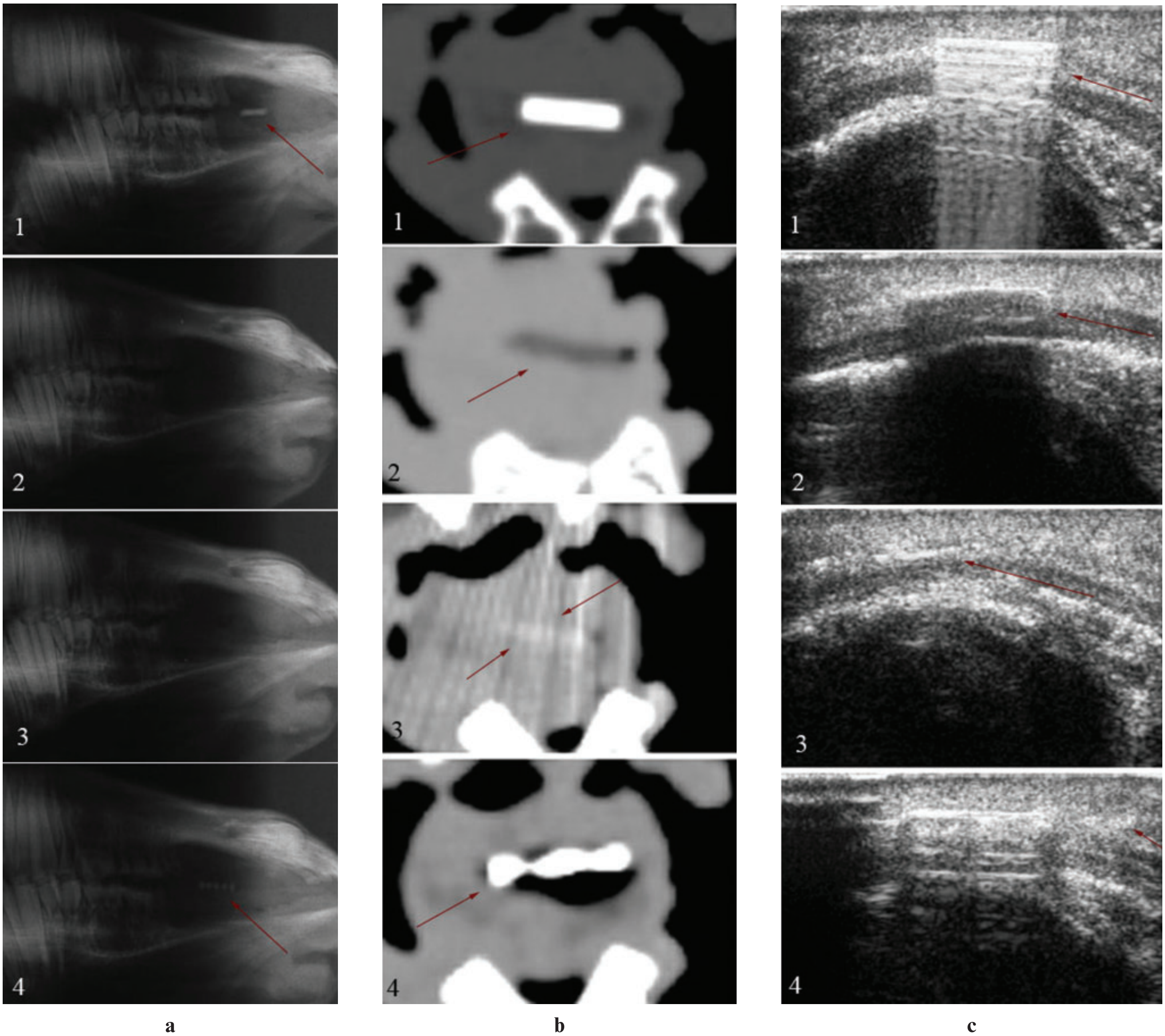


Figure 2 Visibility of foreign body in muscle. (a) Conventional plain radiography. (b) CT. (c) Ultrasonography. 1, glass; 2, dry wood; 3, acrylic; 4, graphite

body showed artefacts during imaging with CT; however, these artefacts did not cause localization errors. Metal, glass, stone and graphite foreign bodies were clearly detected between bone and muscle, whereas acrylic and Bakelite were not demonstrated clearly. Moreover, wood could not be seen at all. Metal, glass, stone and graphite foreign bodies were clearly detected in the muscle, whereas wood, acrylic and

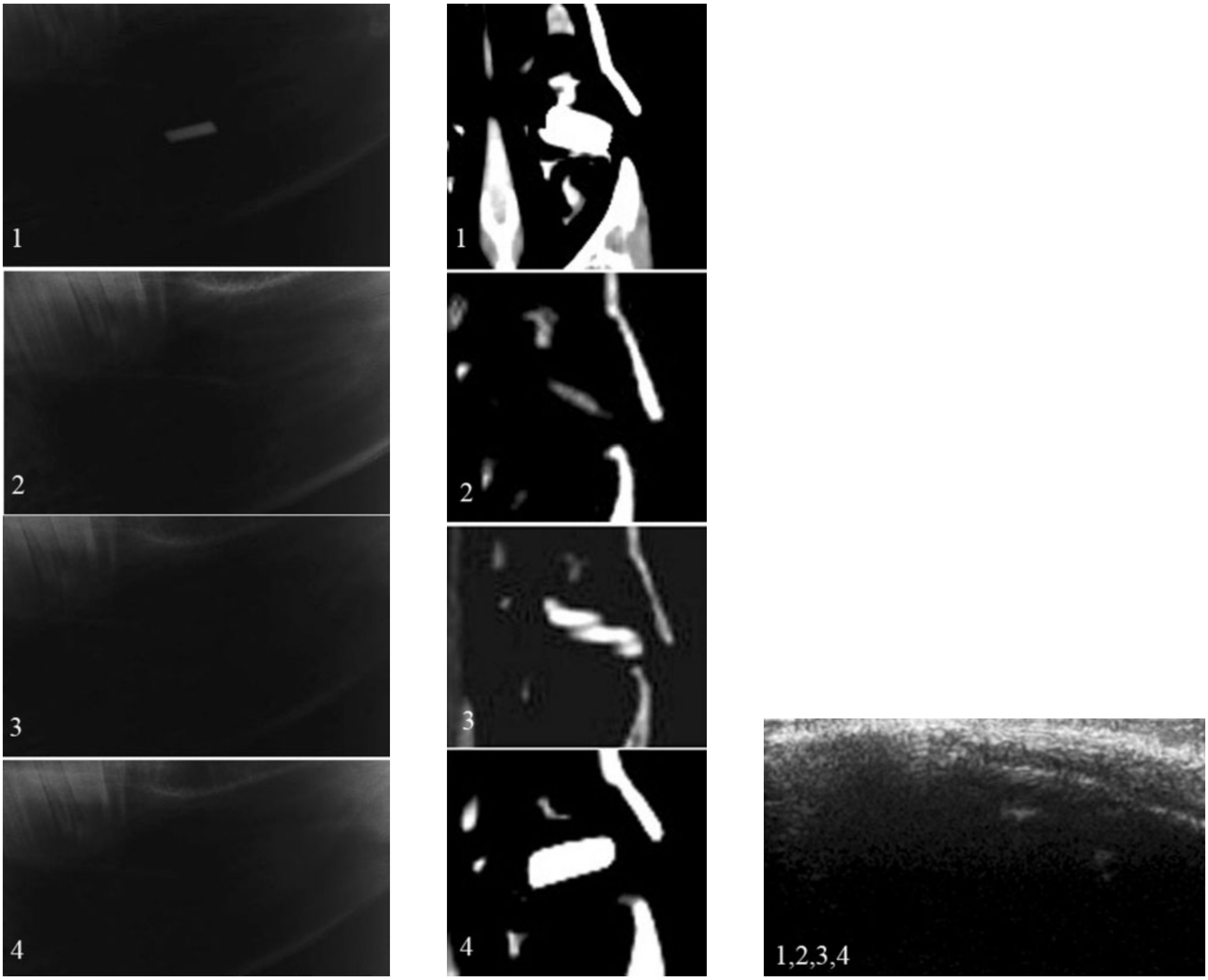
Table 4 Image quality of foreign bodies in various regions observed *via* CT

CT	*Visibility on bone*	*Visibility in muscle*	*Visibility in air*
Metal	++++	++++	++++
Glass	+++	++++	++++
Wood	0	+	++
Stone	++++	++++	++++
Acrylic	+	++	++
Graphite	+++	++++	++++
Bakelite	++	++	++++

Table 5 Image quality of foreign bodies in various regions observed *via* ultrasonography

Ultrasonography	*Visibility on bone*	*Visibility in muscle*	*Visibility in air**
Metal	+++	++++	0
Glass	+++	++++	0
Wood	++	+++	0
Stone	+++	+++	0
Acrylic	++	+	0
Graphite	+++	+++	0
Bakelite	+	+++	0

*It is not possible to evaluate the foreign bodies' visibility in the air with ultrasonography.



a b c

Figure 3 Visibility of foreign body in air. (a) Conventional plain radiography. (b) CT. (c) Ultrasonography. 1, metal; 2, dry wood; 3, graphite; 4, Bakelite. Note that it is not possible to evaluate the foreign bodies' visibility in air with ultrasonography. For this reason, only one figure was submitted to represent all bodies.

Bakelite were demonstrated with difficulty. All foreign bodies placed into the sinus were detected clearly with CT (Figures 1b, 2b and 3b).

Ultrasonography
Table 5 summarises the visibility of the foreign bodies in the ultrasonography images. The images of the metal and glass foreign bodies show artefacts at the time of ultrasonography; however, these artefacts did not cause localization errors. Metal, glass, stone and graphite foreign bodies were clearly detected between bone and muscle, whereas wood, acrylic and Bakelite were not shown clearly. Metal, glass, wood, stone, graphite and Bakelite foreign bodies were clearly detected in the muscle, whereas acrylic was demonstrated with difficulty. All foreign bodies placed into the sinus were not demonstrated with ultrasonography (Figures 1c, 2c and 3c).

Discussion

When a foreign body accidentally enters a human body, it may locate in any of the three different regions. It may locate in an air-filled cavity such as the maxillary sinus, in soft tissue such as the tongue or between bone and muscle.[3] This study investigated these three different relevant situations in *in vitro* models. Foreign bodies were placed between the corpus mandible and muscle in the sheep's head, in the sheep's tongue and in the maxillary sinus of the sheep's head.

Different foreign bodies exhibit different physical properties when displayed *via* different visualization techniques. A foreign body might be overlooked with one method and successfully detected with another. Generally, the selection of the visualization technique to detect a foreign body should depend on its position, composition and size.[3,4] Metal, glass, wood, stone, acrylic, graphite, Bakelite, thorns and sand foreign bodies have been reported in the literature.[2]

Various imaging modalities, such as conventional plain radiographs, CT, MRI and ultrasonography are used to detect foreign bodies. Conventional plain radiography is usually the preferred imaging method for detecting foreign bodies. Conventional plain radiographs can determine a foreign body's position and help radiologists to determine whether the object is in a critical location or not. Although it is used frequently, additional imaging modalities may be needed for exact location.[1] CT is a standard method for imaging and localizing foreign bodies because their shape and size are accurately reproduced. It also enables the exact localization of a foreign body in the patient's body as a prerequisite to being removed surgically.[3] However, metallic artefacts are an important source of error when detecting foreign bodies with CT imaging. If a foreign body's composition is initially unknown, MRI cannot be used as the first diagnostic tool, because artefacts related to the foreign body's composition hinder the clear demonstration of iron, glass, graphite and even plastic.[5] Ultrasonography might be useful for locating superficial foreign bodies; however, it might be unsuitable for those located deep and inside the air-filled cavities.[6] In the present study, metal images in CT visualization, and metal and glass images in ultrasonography visualization showed metallic artefacts; however, these artefacts did not affect the localization.

A non-radiopaque foreign body does not produce a signal on X-ray-based imaging. Hence, the composition of a foreign body determines whether it is visible on the image or not, and whether its size can influence the intensity and dimensions on imaging or not. Thus, a foreign body might be overlooked with one method and successfully detected with another method. A foreign body becomes visible when the grey-scale level at its location differs sufficiently from that of the surroundings. However, it may be invisible when its size get smaller.[1] Seven different foreign bodies were used with the dimensions of about $1 \times 1 \times 0.1$ cm in the study. In spite of the fact that the size of the foreign bodies used in the study were not too small, some of them were invisible in some imaging techniques.

Metallic materials, except aluminium, and glass of all types are opaque on radiographs, so visualizing these materials is easier than non-opaque ones.[2] Metal, glass and stone foreign bodies can be detected with all visualization techniques in all the zones examined in this study because they are opaque on radiography.

Diagnosing non-opaque objects may be more difficult. In selected cases, CT and ultrasonography offer hope for visualizing suspected non-opaque foreign objects in the body.[2] Wood, acrylic and Bakelite could not be observed with conventional plain radiography because of their insufficient opacity. However, graphite in the muscle was visible with conventional plain radiography although it could not be observed in the air and on the bone surface in this study. Usually the preferred visualizing technique is conventional plain radiography for detecting foreign bodies.[6] But this study shows that this method is not effective for observing most of the non-opaque materials.

There are many advantages of ultrasonography. It causes no radiation exposure, provides real-time imaging and is relatively inexpensive. Moreover, it is easily available and can be done at the bedside. Ultrasound has shown promising results, particularly in detecting radiolucent foreign bodies.[7,8] Ultrasonography has a reported sensitivity of 95% for detection of foreign bodies.[8] Although all non-opaque materials except graphite could not be seen clearly between muscle and bone and in muscle with conventional plain radiography, and also the non-opaque materials (except graphite) were not detected clearly with CT between bone and muscle or in the muscle, ultrasonography showed a clear image of all of the tested non-opaque materials except acrylic in the muscle and Bakelite on the bone in this study. This result shows that ultrasonography is more efficient than the other methods at exploring superficial foreign bodies. However, the major disadvantage of ultrasonography occurs in the visualization of air. It is not possible to evaluate the foreign bodies' visibility in air with ultrasonography. Additionally, Manthey and colleagues[9] have suggested that ultrasound should not be relied on to rule out the possibility of a retained foreign body in the distal extremities.

Because location, position, size and shape of the foreign body can be reproduced accurately, CT can be used especially to deepen foreign body imaging.[1] Therefore, some authors have suggested that CT is the standard imaging technique for observing foreign bodies.[3] Nevertheless, all foreign bodies were visible in air with CT visualization in the present study; interestingly, wood could almost not be observed clearly between bone and muscle with CT.

In summary,

- radiopaque foreign bodies are detected with all the visualization techniques
- CT is the best imaging technique for visualization of foreign bodies in air among CT, ultrasonography and conventional plain radiography
- most foreign bodies with low radiopacity become less visible or almost invisible in muscle tissue and between bone and muscle tissue with CT or conventional plain radiography
- ultrasonography visualizes foreign bodies with low radiopacity better, relatively, than CT does.

In other words, if a foreign body is in superficial body tissue, ultrasonography can detect and localize it more efficiently than CT or conventional plain radiography.

References

1. Eggers G, Welzel T, Mukhamadiev D, Wortche R, Hassfeld S, Muhling J. X-ray-based volumetric imaging of foreign bodies: a comparison of computed tomography and digital volume tomography. *J Oral Maxillofac Surg* 2007; **65**: 1880–1885.
2. Hunter TB, Taljanovic MS. Foreign bodies. *Radiographics* 2003; **23**: 731–757.
3. Eggers G, Mukhamadiev D, Hassfeld S. Detection of foreign bodies of the head with digital volume tomography. *Dentomaxillofac Radiol* 2005; **34**: 74–79.
4. 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**: 119–124.
5. Lagalla R, Manfre L, Caronia A, Bencivinni F, Duranti C, Ponte F. Plain film, CT and MRI sensibility in the evaluation of intraorbital foreign bodies in an in vitro model of the orbit and in pig eyes. *Eur Radiol* 2000; **10**: 1338–1341.
6. 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**: e71–75.
7. 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**: 401–403.
8. Jacobson JA, Powell A, Craig JG, Bouffard JA, van Holsbeeck MT. Wooden foreign bodies in soft tissue: detection at US. *Radiology* 1998; **206**: 45–48.
9. 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.