ORIGINAL RESEARCH

Comparative Sensitivity Assessment of Cone Beam Computed Tomography and Digital Radiography for detecting Foreign Bodies

[1]Sima Sadat Lari, [2]Abbas Shokri, [3]Seyyed Mohammad Hosseinipanah, [4]Shahin Rostami, [5]Shabnam Seyedzadeh Sabounchi

ABSTRACT

Aim: Foreign body detection and determining whether it is adjacent to critical organs has a significant role in its removal. Various imaging techniques have been used to locate foreign bodies. This study aimed to compare cone beam computed tomography (CBCT) and digital radiography for detecting foreign bodies in an *in vitro* model.

Materials and methods: Foreign bodies composed of normal glass, barium glass, wood, and stone with two sizes were placed into three different locations of two sheep heads. Digital radiography [lateral cephalometric, submentovertex (SMV)] and CBCT were compared to investigate their sensitivity for detecting foreign bodies.

Results: Diagnostic sensitivity of digital radiography in lateral cephalometric view, SMV view, and CBCT for detecting all types of foreign bodies was 67.2, 32.3, and 76.6% respectively. None of these techniques were successful in detecting wood satisfactory. Stone was detected relatively higher than other foreign bodies (82.6%). Diagnostic sensitivity of CBCT in detecting foreign bodies was 100%, except for wood. Accuracy of imaging techniques in detecting foreign bodies according to locations in descending order was lip, mandibular angle, and maxillary sinus.

Conclusion: It can be concluded that appropriate amount of radiopacity is enough for CBCT to exactly detect foreign body, regardless of its location or size.

[1,2]Dental Research Center, Department of Oral and Maxillofacial Radiology, School of Dentistry, Hamadan University of Medical Sciences, Hamadan, Islamic Republic of Iran

[3]Department of Anatomical Sciences, Hamadan University of Medical Sciences, Hamadan, Islamic Republic of Iran

[4]Private Practice, Hamadan, Islamic Republic of Iran

[5]Dental Research Center,Department of Community Oral Health, School of Dentistry, Hamadan University of Medical Sciences, Hamadan, Islamic Republic of Iran

Corresponding Author: Shabnam Seyedzadeh Sabounchi Assistant Professor, Department of Dentistry and Community Oral Health, Hamadan University of Medical Sciences 6516866487, Hamadan, Islamic Republic of Iran, Phone: 08138223705, e-mail: shsab1@yahoo.com

Clinical significance: In maxillofacial traumatic patients, CBCT seems to be a better and cost-effective technique for detecting hidden foreign bodies than other routine techniques.

Keywords: Cone beam computed tomography, Detection, Foreign body, Radiography.

INTRODUCTION

Foreign bodies frequently occur in the maxillofacial region and account for 3.8% of pathologies in this area.[1] A considerable number of surgeries around the world are conducted annually to remove foreign bodies. Foreign bodies can cause various complications and side effects in patients as well as inhibiting wound healing by developing inflammation and granulum.[2] Therefore, early removal of foreign bodies is necessary for the prevention of maltreatment and development of more severe problems such as intracranial abscess in patients.[1-3]

Accurate localization of foreign bodies and verifying type of foreign body are critical in assisting the surgeon in foreign body retrieval.[3] Furthermore, determining whether the foreign body is near a vital structure or not and calculating the risks of surgery for the patient are required before foreign body removal.[4] In general, diagnosis and clarification of foreign body location are based on patient history, clinical, and radiographic examination.[5]

Conventional plain radiographs, computed tomography (CT), ultrasonography, magnetic resonance

imaging (MRI), and cone beam CT (CBCT) can be employed to detect foreign bodies. Most common foreign bodies in the head and neck soft tissue are reported as wood splinters, glass fragments, and metallic objects.[3] Barium glass and small pebbles that are usually found in car accident incidents are not commonly investigated. The aim of this study was to investigate the sensitivity of digital radiography [lateral cephalometric, submentovertex (SMV)] and CBCT for identifying foreign bodies inside *in vitro* models.

MATERIALS AND METHODS

Four different types of materials that are typically found as foreign bodies in maxillofacial traumas were investigated in an *in vitro* study. In this study, four different foreign bodies made of barium glass, normal glass, wood, and small pebbles were placed in three different locations in the head and neck area of two sheep head 1 day after they were slaughtered as described below.

Foreign Bodies on Bone Surface

Foreign bodies were placed between the corpus mandible and muscle in a sheep's head with a scalpel by preparing a slot in the muscle.

Foreign Bodies in Connective Tissue

In the connective tissue with a scalpel, a tunneling gap was prepared in the lip and the foreign body was placed horizontally in the middle of the sheep's lip.

Foreign Bodies in Air

Particles were placed into the sheep's maxillary sinus. A triangular window was opened in the crestal ridge of the maxilla with a sharp osteotome. After placing the foreign body directly into the sinus, the window was closed (Fig. 1).
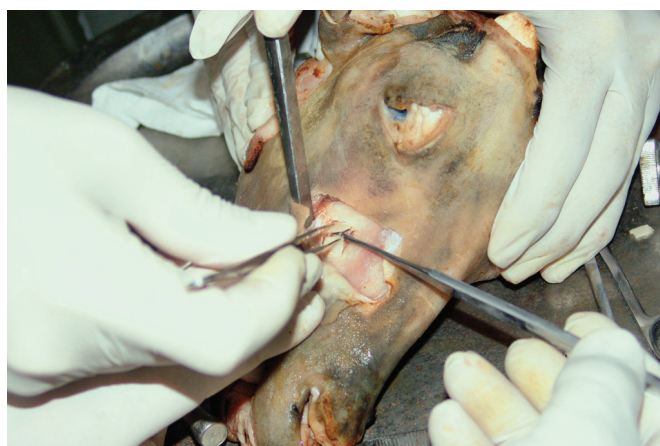
In total, four different material types of foreign bodies were prepared in two different dimensions: $1 \times 1 \times 0.2$ cm and $0.3 \times 0.3 \times 0.2$ cm. All four particles were placed in three different locations of two sheep head and three different imaging methods were used for imaging in order to provide 72 different images that were analyzed by four observers leading to report of 288 observations.

Three different imaging methods, lateral cephalometric, SMV, and CBCT, were used to compare their ability in detecting foreign bodies in the sheep heads.

Lateral Cephalometric Radiography

Conventional plain film imaging was performed using the lateral cephalometric mode of a PromaxScara 2 (Planmeca, Helsinki, Finland). 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 seconds.

Submentovertex Radiography

The digital radiographic device PromaxScara 2 (Planmeca, Helsinki, Finland) with exposure setting of 54 kVp, 5 mA, and 18.7 seconds was used for obtaining SMV radiographs.

Due to two-dimensional properties of the lateral cephalometric and SMV radiographs, it was necessary to fixate the sheep head, as there was a possibility of encountering asymmetry in the images. So, a metal fix rod was designed and attached to foramen magnum to hold the sheep head and prevent displacement of the head during scanning and changing different foreign bodies (Fig. 2). Digital radiographies were captured by two methods of lateral cephalometry and SMV (Figs 3 and 4).

Cone Beam Computed Tomography

The CBCT images were obtained with a NewTom3G (NewTom, Verona, Italy). Operating parameters were set at 3.6 mA and 110 kV and exposure time was 1.8 seconds.

Fig. 1: Placement of foreign body in the maxillary sinus of the sheep head

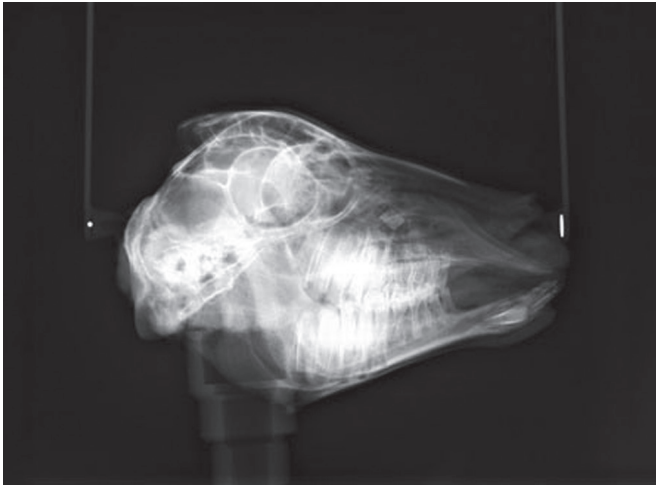**Fig. 2:** Fixation of sheep head on metal rod in Planmeca device

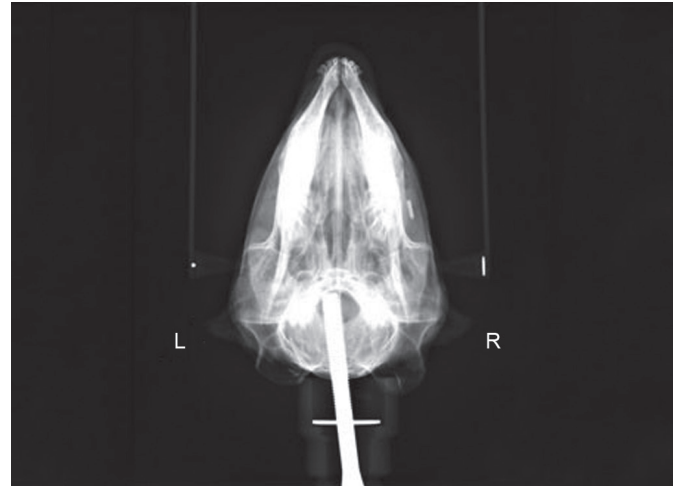**Fig. 3:** Lateral cephalometric radiography of sheep head

Fig. 4: Submentovertex radiography of sheep head

As the type of CBCT used in this study was gantry and supine position and the image was restructured in volume, there was no need to fix the sheep head and it was placed in the determined location. Cone beam computed tomography images were analyzed by NNT viewer software (NewTom, Verona, Italy) and reconstructed to be viewed in coronal, sagittal, and axial plan (Fig. 5). Foreign bodies were placed in one side of the sheep head as cases and the other side was considered as control. In order to increase precision and reduce error in observations, foreign bodies were imaged one a time.

The images were analyzed to assess each foreign body's visibility on a four-point scale with the anchors "bad image" (1+) to "excellent image" (4+) as follows:

Bad image: Details not resolved, bad demarcation from surrounding, bad visibility

Fair image: Insufficient resolution of details, insufficient visibility, insufficient demarcation

Good image: Good resolution of details, demarcation from surrounding, clear visibility

Excellent image: Excellent resolution of details and excellent visibility, good demarcation from surrounding.

The images were independently assessed by four different observers, two of whom were oral and maxillo-

facial radiologists and two were oral and maxillofacial surgeons. 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.

Approval for conducting this study was obtained from the research ethics committee of the Hamadan University of Medical Sciences in September 2012. Data were analyzed with statistical package for the social sciences (SPSS) statistical software, version 19.00 (SPSS Inc., Chicago, IL). Variables were described by using means and standard deviations (SDs) displayed in tables and figures. Furthermore, sensitivity, specificity, and Kappa statistics were measured.

RESULTS

Kappa statistics coefficient between radiologists and oral maxillofacial surgeons was measured appropriate at 0.89. Sensitivity, specificity, and accuracy of different radiographic imaging techniques have been demonstrated in Table 1. Diagnostic sensitivity of CBCT method was higher than lateral cephalometry and sensitivity of lateral cephalometry was higher than SMV (Table 1). However, CBCT, and SMV had high specificity; 100 and 99% respectively for diagnosing foreign bodies, but lateral cephalometry had only 34.4% specificity (Table 1).

Also, accuracy of three different imaging methods, CBCT, SMV, and lateral cephalometry, was 88.28, 65.62, and 50.78% respectively, and the differences
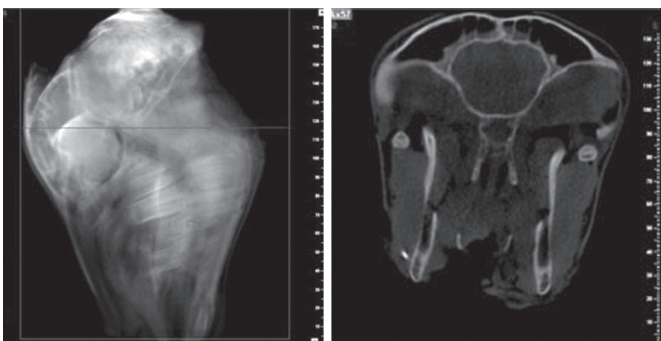
Fig. 5: Cone beam computed tomography radiography of sheep head

Table 1: Sensitivity, specificity, accuracy of cone beam computed tomography, submentovertex, and lateral cephalometry imaging methods (numbers by percentage)

Imaging method	Sensitivity	Specificity	Accuracy
Lateral cephalometry	67.2	34.4	50.78
SMV	32.3	99.0	65.62
CBCT	76.6	100.0	88.28
Total	58.7	77.8	68.22

were statistically significant ($\chi^2(2) = 126.4$, p < 0.001) (Table 1).

According to the diagnostic accuracy of different foreign bodies used in this study, the highest diagnostic accuracy has been recorded for small pebbles (75.6%) and least accuracy for wood (50.6%). Furthermore, diagnostic sensitivity of normal glass was 71.5% and barium glass, 78.5% that were close to small pebbles at 82.6%.

According to Table 2, least diagnostic accuracy is recorded for lateral cephalomtery imaging method for diagnosing normal glass, barium glass, and wood (each 50%). However, the highest specificity is demonstrated for CBCT in diagnosing normal glass (100%), barium glass (100%), and small pebbles (100%) (Table 2).

Total diagnostic sensitivity for small and large foreign bodies was 61.8 and 55.6% respectively. Sensitivity, specificity, and accuracy of detecting large and small foreign bodies by different imaging techniques have been demonstrated in Table 3.

According to digital radiography quality table, SMV radiographies demonstrate zero code for maxillary sinus location (Table 4). In other locations, image quality of lateral cephalometry was higher than SMV. In

Table 2: Sensitivity, specificity, and accuracy of different material types of foreign bodies (numbers by percentage)

Imaging method	Type of foreign body	Sensitivity	Specificity	Accuracy
Lateral cephalometry	Normal glass	77.1	22.9	50
	Barium glass	91.7	8.3	50
	wood	0.0	100.0	50
	Small pebbles	100.0	6.3	53.12
	Total	67.2	34.4	50.78
SMV	Normal glass	37.5	97.9	67.7
	Barium glass	43.8	100.0	71.87
	wood	0.0	97.9	48.95
	Small pebbles	47.9	100.0	73.95
	Total	32.3	99.0	65.62
CBCT	Normal glass	100.0	100.0	100.0
	Barium glass	100.0	100.0	100.0
	wood	6.3	100.0	53.12
	Small pebbles	100.0	100.0	100.0
	Total	76.6	100.0	88.28

Table 3: Sensitivity, specificity, and accuracy of different imaging methods according to size of foreign bodies (numbers by percentage)

Size	Imaging method	Sensitivity	Specificity	Accuracy
Large	Lateral cephalometry	71.9	30.2	51.04
	SMV	38.5	100.0	69.27
	CBCT	78.1	100.0	89.06
	Total	61.8	76.7	69.27
Small	Lateral cephalometry	62.5	38.5	50.52
	SMV	26.0	97.9	61.92
	CBCT	75.0	100.0	87.5
	Total	55.6	78.8	67.18

Table 4: Image quality of foreign bodies in various locations observed via different imaging methods

Imaging method	Foreign body	Visibility on lip	Visibility on maxillary sinus	Visibility on mandibular angle
Lateral cephalometry (digital radiography)	Normal glass	+++	+	++
	Barium glass	+++	++	+++
	wood	0	0	0
	Small pebbles	++++	++++	+++
SMV (digital radiography)	Normal glass	++	0	+
	Barium glass	++	0	++
	wood	0	0	0
	Small pebbles	+++	0	=
CBCT	Normal glass	++++	++++	++++
	Barium glass	++++	++++	++++
	wood	+	0	0
	Small pebbles	++++	++++	++++

total, CBCT images have the highest code of quality in all three locations for all foreign bodies except for wood (Table 4).

DISCUSSION

The present study evaluated and compared the detection ability of three different imaging methods of four foreign bodies in three different locations and two sizes. According to our findings, sensitivity of digital radiography in lateral cephalomtery, SMV, and CBCT for all types of foreign bodies were 67.2, 32.3, and 76.6% respectively. None of the imaging methods could detect wood foreign bodies, as the diagnostic sensitivity for both lateral cephalometry and SMV was zero and with CBCT was only 6.3%. Among all four foreign bodies investigated in the present study, small pebbles had the highest detection sensitivity (82.6%).

Imaging Methods

In the present study according to diagnostic sensitivity, it was demonstrated that CBCT (76.6%) was higher than lateral cephalometry (67.2%) and SMV (32.3%). All three methods are based on X-ray radiation, but technical properties of three-dimensional techniques have higher resolution in images and detect low opacity corresponding to a higher radiopacity quality than the two other methods.[6] So, foreign bodies such as normal glass particles with low opacity hidden between muscle and bone can be best detected by CBCT.[6]

Detecting nonopaque foreign bodies can cause some difficulties. However, Hunter and Taljanovic[2] have demonstrated that CT and ultrasonography can aid us in imaging nonopaque foreign bodies, such as wood. In the present study, all three different imaging methods had the lowest sensitivity for detecting wood foreign bodies

so that lateral cephalometry and SMV had zero sensitivity and 6.3% for CBCT.

Aras et al[3] reported zero sensitivity for wood foreign body in lateral cephalometric view similar to our study. Quality of image for glass was (+2) in the study by Aras et al[3]; however, in our study, it was +3, +1, and +2 in maxillary sinus, lip, and mandibular angle locations, accordingly. In their study, image quality of small pebbles in mandibular angle was similar to our study (+3) but was one score less than other two locations.[3]

Various studies have studied the ability of different imaging methods in detecting radiolucent foreign bodies. Ober et al[7] demonstrated that CT has higher diagnostic accuracy in demonstrating wood foreign bodies in dog leg than in ultrasound and MRI. However, Turkcuer et al[8] found that ultrasound (90% sensitivity) has higher ability in diagnosing radiolucent foreign bodies in chicken leg than in routine radiographs (5% sensitivity).

Foreign Body Size

Sensitivity of small foreign bodies was slightly lower than larger ones, indicating that the size of foreign body may influence its detection (Table 3). Larger items had higher sensitivity that can be explained by bringing about more dislocations in the surrounding tissues of these items and therefore leading to better diagnosis in radiographic images.

Studies that have investigated detection of foreign bodies in different sizes and with different imaging methods have reached to inconsistent findings. Trommer et al[9] studied the minimum size required for diagnosis with different radiographic imaging methods. They found that the minimum size for detecting iron particles by CT is 0.02 mm and also discovered that CT cannot diagnose different material types especially if they are of small size.[9]

However, some other studies deny the effect of foreign body size on their diagnosis with various imaging methods. In a study by Al-Zahrani et al in a study on 31 patients with suspected radiolucent wood particles in soft tissues, used CT and ultrasound for foreign body detection and results demonstrated that size of foreign body does not influence their diagnosis.[10]

Foreign Body Location

The results of the present study demonstrated that in general, the diagnostic sensitivity of imaging methods used was highest in the lip (69.8%) compared with mandibular angle (63%) and maxillary sinus (43.2%) locations. On the contrary, diagnostic sensitivity of CBCT was similar in all three locations and higher than lateral cephalomteric and SMV, in which SMV had the least sensitivity (Table 4). Furthermore, sensitivity numbers in the two latter imaging methods were in a broader range and dissimilar. The discrepancy in numbers can be rationalized by the observers in the present study, which used restructuring in volume to detect foreign bodies by CBCT method and can ignore the effect of foreign body location. However, location cannot be overlooked due to superimposition of images in lateral cephalometric and SMV methods.

Aras et al[3] had used lateral cephalometric method and showed +2 for quality of images taken from glass foreign bodies in three different locations of lip, maxillary sinus, and mandibular angle; however, in the present study, the numbers were +3, +1, and +2 for the aforementioned locations accordingly. The higher +1 value increase in image quality observed in our study for the soft tissue location can be rationalized by less superimposition in the lip compared with the tongue of the sheep used by Aras et al.[3]

In a study for detecting wood particles in dog leg, it was found that CT had a higher accuracy in detecting wood foreign bodies than ultrasound and MRI, in which the latter method had the least accuracy.[11]

The results of a study that imaged wood foreign bodies placed in chicken leg by conventional radiography, CT, MRI, and ultrasound demonstrated that CT and ultrasound had similar ability in detecting wood particles and MRI had less sensitivity.[12] However, conventional radiography had the least sensitivity in detecting wood particles in this location.[12] The results of Turkcuer et al[8] are also in accordance with Venter et al[12] in showing higher diagnostic accuracy for ultrasound than conventional radiography.

Different studies have investigated ability of foreign body detection with various imaging methods. According to our rapid literature review, limited studies have explored CBCT foreign body detection according to size and location in human body.[3,5,8,13] One of the strengths of the present study is that diagnostic sensitivity of CBCT was compared with digital radiography by taking into account different variables, such as composition and location of foreign bodies. In addition, four observers (two oral and maxillofacial surgeons and two radiologists) had examined the images that improved the accuracy of diagnostic sensitivity.

The limitation for this study was that it was not conducted on human bodies regarding ethical issues, limited number of cadavers, and difficulty in taking and preparing radiographic images from them. However, by selecting sheep head as a representative mammal with similarities to human head and ability to reduce the time interval between scarification and assessment, the validity and reliability of the results was improved.

CONCLUSION

Sensitivity, specificity, and diagnostic accuracy of CBCT in detecting foreign bodies except for wood was 100%. Diagnostic accuracy of different imaging methods in detecting foreign bodies in lip was higher than mandibular angle and in mandibular angle higher than maxillary sinus. Based on findings of the present study, diagnostic accuracy of CBCT in detection of foreign bodies was high and similar in different locations compared with other imaging radiographic methods. However, higher dose, time, and cost of CBCT than other digital radiographs need to be reassessed in order to suggest CBCT as the first option for diagnosing patients susceptible to presence of foreign bodies.

REFERENCES

1. Eggers G, Welzel T, Mukhamadiev D, Wrtche R, hasfeld 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 Sep;65(9):1880-1885.
2. Hunter TB, Taljanovic MS. Foreign bodies. Radiographics 2003 May-Jun;23(3):731-757.
3. Aras MH, Miloglu O, Barutcugil C, Kantarci M, Ozcan E Harorli A. Comparison of the sensitivity for detecting foreign bodies among conventional plain radiography, computed tomography and ultrasonography. Dentomaxillofac Radiol 2010 Feb;39(2):72-78.
4. Enislidis G, Wagner A, Ploder O, Ewers R. Computed intraoperative navigation guidance—a preliminary report on a new technique. Br J Oral Maxillofac Surg 1997 Aug;35(4):271-274.
5. Oikarinen KS, Nieminen TM, Mäkäräinen H, Phytinen 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 Apr;22(2):119-124.
6. Reiner B, Siegel E, McLaurin T, Pomerantz S, Allman R, Hebel JR, Fritz S, Protopapas Z. Evaluation of soft-tissue foreign bodies: comparing conventional plain film radiography, computed radiography printed on film, and computed radiography displayed on a computer workstation. Am J Roentgenol 1996 Jul;167(1):141-144.
7. Ober CP, Jones JC, Larson MM, Lanz OI, Were 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 Sep-Oct;49(5):411-418.
8. Turkcuer I, Atilla R, Topacoglu H, Yanturali S, Kiyan S, kabakci N, Bozkurt S, Cevik AA. Do we really need plain and soft-tissue radiographies to detect radiolucent foreign bodies in the ED? Am J Emerg Med 2006 Nov;24(7):763-768.
9. Trommer G, Kösling S, Nerkelun S, Gosch D, Klppel R. [Detection of orbital foreign bodies by CT: are plain radiographs of foreign bodies still useful?] Rofo 1997 Jun;166(6):487-492. German.
10. Al-Zahrani S, Kremli M, Saadeddin M, Ikram A, Takroni T, Zeidan H. Ultrasonography detection of radiolucent foreign bodies in soft tissue compared to computed tomography scan. Ann Saudi Med 1995 Mar;15(2):110-112.
11. Lue AJ, Fang WD, Manolidis S. Use of plain radiography and computed tomography to identify fish bone foreign bodies. Otolaryngol Head Neck Surg 2000 Oct;123(4):435-438.
12. Venter NG, Jamel N, Marques RG, Djahjah F, Mendonca Lde S. [Evaluation of radiological methods for detection of wood foreign body in animal model. Acta Cir Bras 2005;20(Supp 1): 34-41.
13. Shresta D, Sharma UK, Mohammad R, Dhoju D. The role of ultrasonography in detection and localization of radiolucent foreign body in soft tissues of extremities. J Nepal Med Assoc 2009 Jan-Mar;48(173):5-9.