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Diagnostic Accuracy of Cone Beam Computed Tomography in Identification of Foreign Bodies in the Head and Neck Region

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Objectives This study aimed to assess the identification of traumatic foreign bodies in the head and neck region using cone-beam computed tomography (CBCT).
Methods In this study, samples (1×1×0.1 cm) were fabricated from 6 different types of materials commonly found in various head and face traumas. These materials included iron, glass, stone, wood, asphalt, and tooth. They were located in 3 different areas, including the tongue, airway, and vestibule of 3 sheep heads. Ten scans were acquired from these materials embedded in different regions. A total of 180 images were analyzed by 2 observers and rated in terms of visual clarity of the foreign body. The results were analyzed by the Kruskal-Wallis test.
Results In 100% of images, stone, asphalt, and glass were observed in all 3 areas with high resolution. On the other hand, 100% of images were unclear in all evaluated areas with metal artifacts. Tooth images were found to be excellent in 100% of cases in the muscle and airway regions and 80% of cases in the vestibule region (unclear in 20% of cases). However, wood was not detected in 100% of images from the tongue and vestibule regions. It was not detected on 60% of images from the airway, while it was found on 40% of images with low resolution.
Conclusion CBCT detected and located all opaque objects such as iron, glass, stone, asphalt, and tooth. However, it showed limited potential in detecting radiolucent objects such as wood.
Keywords Cone-Beam Computed Tomography; Foreign bodies; Maxillofacial Injuries

Introduction

Foreign bodies in the head and neck region often enter the body due to various events, such as traffic accidents, explosions, bullet wounds, or therapeutic interventions in the maxillofacial area. They are responsible for 3.8% of pathological findings in this area[1]. The composition, type and location of the foreign bodies may vary depending on the type of trauma[2, 3].
Common objects in the soft tissues of the head and neck region include wood straps, glass pieces, metal objects, rock and gravel particles[4]. The side effects of foreign bodies in the maxillofacial region include pain, discomfort, swelling and tenderness, cellulite and abscess formation, migration to distant areas, and potential vascular or nerve damage[5]. Infection, inflammation, and pain are among the possible complications of foreign bodies[4, 6].
Detecting the location of a foreign body is accomplished based on the patient's history, clinical examination, and imaging. In order to find foreign bodies, various imaging methods are applied. Several studies have been conducted to evaluate various imaging modalities in detecting the foreign bodies; in this regard, Oikarinen et al.[1], Al-Zahrani et al.[7], Venter et al.[8], Aras et al.[9], and Kaviani et al.[10] have introduced different methods including 2D radiography, computed tomography (CT), magnetic resonance imaging (MRI), and ultra-sonography. Conventional radiography is the primary imaging modality for detection of the foreign bodies; however, superimposition of tissues in the path of the X ray beam is the main drawback of 2D imaging[11]. CT is a standard method for imaging and detecting the location of foreign bodies, as the shape, size, and position of objects are properly reconstructed[12]. It also detects the exact location of the foreign body. However, metal artifacts are one of the major disadvantages of this imaging modality[13].
The present study aimed to analyze the efficacy of CBCT in detection of foreign bodies in 3 areas of the tongue, airways, and vestibule.

Materials and Methods

This study was approved b they research committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran.
In this analytical observational in vitro study, six different materials (1×1×0.1 cm) were selected as the foreign bodies. The selected materials included the most common materials found as foreign bodies due to trauma to the head and neck region: iron, glass, stone, dried wood, asphalt, and tooth. The materials were embedded in three sheep heads. Each of the foreign bodies was embedded in 3 areas of the sheep heads. These areas included the tongue, airways, and

vestibule. The foreign bodies were embedded in the muscle tissues (of the tongue) with a scalpel cut through the muscle. Each sample of foreign bodies was embedded separately in 3 areas and imaging was carried out. This procedure was repeated 10 times, and a total of 180 imaging procedures were carried out. A NewTom VGi CBCT scan system (QR, Verona, Italy) was used for imaging with a large field of view (FOV; 8×12 cm) and standard resolution (150 μm voxel size, 110 kVp, 3.3 mA). Imaging was carried out at the oral and maxillofacial Radiology Department of Shahid Beheshti University of Medical Sciences.

The images were analyzed using NNT Viewer software version 8 (NewTom; Verona, Italy) and independently viewed by 2 experienced observers (oral and maxillofacial radiologists). The collected data were recorded in the code sheets. Each image was rated based on the visual clarity as visible with good resolution (code 1), visible with poor resolution (code 2), and invisible (code 3):

Code 1: The object is clearly visible with its exact dimensions (good resolution).

Code 2: The outer borders of the object are unclear or its dimensions are not clearly identified due to metal artifacts (poor resolution).

Code 3: The object is by no means visible (invisible).

The Kruskal-Wallis test was used to analyze the collected data and to compare the visibility of different materials in the evaluated areas.

The inter-examiner and intra-examiner reliability were determined by comparing two repeated measurements at 10 randomly chosen images at 1 month apart, with 95% limits of agreement extended by a 95% confidence interval for differences between the means (using the Kappa coefficient).

Results

The intra-class correlation coefficients (ICCs) demonstrated a high degree of reliability between the first and second replicates with ICC values exceeding 0.95.

The Kruskal-Wallis test showed that image clarity was not significantly different among the evaluated materials (glass, metal, teeth, stone, and asphalt) in the evaluated areas; the difference was only significant for wood (P=0.012). However, pairwise comparisons of materials in different areas using Dunn-Bonferroni test showed a significant difference in wood clarity in the tongue and airways versus the vestibule (P=0.029). Nevertheless, the difference between the tongue and vestibule was not significant (P=1). Only wood could not be located in 60% of cases, while the rest of foreign bodies were visible.

As presented in Table 1, iron was 100% unclear and observed with artifact in the tongue area. However, glass, stone, asphalt, and tooth were 100% clear. Wood was not detected in any of these images.

As presented in Table 2, iron was 100% unclear with artifacts in the airway. However, glass, stone, asphalt, and tooth were 100% clear. Wood was not adequately clear in 40% of images; it was completely unclear in 60% of cases.

As presented in Table 3, iron was 100% unclear with artifacts in the vestibule region. However, glass, stone, and asphalt were 100% clear on the images. It should be noted that wood was not detected in any of these images.

Table 1- Clarity of foreign bodies in the tongue area

		Clear	Unclear	Not detected
		N%	N%	N%
Tongue	Iron	0(0%)	10(100%)	0(0%)
	Glass	10(100%)	0(0%)	0(0%)
	Stone	10(100%)	0(0%)	0(0%)
	Wood	0(0%)	0(0%)	10(100%)
	Asphalt	10(100%)	0(0%)	0(0%)
	Tooth	10(100%)	(%٠)0	0(0%)

Table 2- Clarity of foreign bodies in the airway area

		Clear	Unclear	Not detected
Airway	Iron	0(0%)	10(100%)	0(0%)
	Glass	10(100%)	0(0%)	0(0%)
	Stone	10(100%)	0(0%)	0(0%)
	Wood	0(0%)	4(40%)	6(60%)
	Asphalt	10(100%)	0(0%)	0(0%)
	Tooth	10(100%)	0(0%)	0(0%)

Table 3- Clarity of foreign bodies in the vestibule

		Clear	Unclear	Not detected
Vestibule	Iron	0(0%)	10(100%)	0(0%)
	Glass	10(100%)	0(0%)	0(0%)
	Stone	10(100%)	0(0%)	0(0%)
	Wood	0(0%)	0(0%)	10(100%)
	Asphalt	10(100%)	0(0%)	0(0%)
	Tooth	8 (80%)	2(20%)	0(0%)

Discussion

Different imaging modalities are used for detection of foreign bodies in the maxillofacial region such as plain radiography, CBCT, MRI, CT, and ultrasound. Plain radiographs can be used to detect foreign bodies and to reveal if they are in a critical location. Although this modality is commonly used, other techniques may be required for exact localization of the foreign bodies[14, 15].

CT is a standard imaging modality for detection of foreign bodies because the shape and size of objects are accurately reconstructed in this method. CT also determines the exact position of foreign bodies and enhances their surgical removal. However, metal artifacts can cause errors in detection of foreign bodies on CT scans. In the head and neck region, CBCT has advantages over CT. CBCT is more affordable and has a lower patient radiation dose than CT[13]. In addition, less metal artifacts are seen on CBCT images in contrast to CT images.

This study analyzed the potential of CBCT systems in detecting foreign bodies. In this study, 6 types of different foreign body materials (iron, glass, stone, wood, asphalt, and tooth) placed in 3 different parts of the oral and maxillofacial region (tongue, vestibule and airway) were used. Images of iron in all 3 areas of the tongue, vestibule and airway contained artifacts (code 2, 100% unclear). Glass, stone, and asphalt were observed on 100% of images in all 3 areas with high resolution. Wood was not detected in the tongue or vestibule on 100% of scans. In the airway area, 40% of cases were detected with low resolution. Considering the similar density of wood to the adjacent tissues, it would be undetectable if embedded adjacent to the airways. However, when wood is floating in the airway, it can be detected with low resolution due to the different density of wood compared with the surrounding air. Tooth was observed with high resolution in the tongue and airway areas. However, the resolution was low in 20% of images from the vestibule region probably due to the presence of dentin. On 80% of images, tooth was detected with high resolution.

In a study by Bray et al.[14] which aimed to compare ultrasonography with CT scan in detecting radiolucent foreign bodies, it was concluded that ultrasonography is a reliable method in detecting radiolucent foreign bodies in the soft tissues. This finding was consistent with the present study, as we also concluded that CBCT is not efficient in detecting wood.

Furthermore, in a study by Kaviani et al.[10] which aimed to compare the sensitivity of CT, CBCT, MRI, and ultrasound in detecting foreign bodies, it was concluded that CBCT is the best method for detecting and locating the foreign bodies due to low radiation dose and low cost. CT is not recommended due to its limited access. For objects with low opacity, MRI and ultrasound are recommended[16]. Nevertheless, in a study by Venter et al.[8] which aimed to compare conventional imagining systems with MRI, ultrasound, and CT in detecting wooden foreign bodies, it was concluded that ultrasound is the most effective imaging modality. These results were consistent with the present study, as we also showed that CBCT is not capable of detecting lucent objects such as wood.

In a study by Javadrashid et al.[15] which aimed to compare the diagnostic power of CT, MRI, and ultrasound systems in detecting various foreign bodies, it was concluded that all foreign bodies, except wood, were detected by CT scan. However, only ultrasonography detected wood. These results were consistent with the present study, as we also showed that all objects, except wood, were detected and located by CBCT. In a study by Valizadeh et al.[16] it was concluded that in CBCT images, the position of foreign bodies (iron, glass, stone, asphalt, and tooth) in various areas had no effect on their visibility. However, this finding did not apply to wood, as it was visible in the nasal area due to contrast with the surrounding air; these results were consistent with the present study.

Moreover, in a study by Eggers et al.[17] which aimed to analyze the efficacy of CT and CBCT in detecting 6 foreign bodies, although the quality of CBCT images was lower than that of CT, the difference was not clinically significant. Thus, CBCT was recommended due to the lower radiation dose for detecting foreign bodies in the maxillofacial region. In a study by Lari et al.[12] which aimed to compare radiographic images with CBCT in detecting foreign bodies, it was concluded that radiographic images were superior to ultrasound in evaluation of radiopaque objects. Shokri et al.[18] also concluded that CBCT images are superior to ultrasound and MRI in detecting objects with high opacity. In the present study, we also concluded that CBCT is appropriate for detecting foreign bodies with high opacity in the jaw and facial area. In a study by Aras et al.[9] which aimed to compare the accuracy of conventional radiography, CT, and ultrasound in detecting foreign bodies, it was concluded that ultrasound is more effective than CT and conventional radiography in detecting the location of superficial foreign bodies with low radiopacity in tissues. Nevertheless, CT was more effective than ultrasound and conventional radiography in visualization of foreign bodies in the air. Similarly, we concluded that CBCT is more effective in detecting foreign bodies. Nevertheless, ultrasound is more efficient in detecting objects with low radiopacity such as wood.

In conclusion, the results of the present study showed that CBCT with advantages such as lower radiation dose and lower cost can be used for detecting foreign bodies and their localization in cases with limited access to CT scan. Although CBCT is not suitable for detection of low-density foreign bodies, MRI or ultrasonography can be recommended for such cases.

Materials used in this study were mostly foreign bodies due to accidents. Accordingly, it is suggested that future studies concentrate on dental materials. Materials such as amalgam, composite, gutta-percha, needles, and other common materials in dentistry are likely to break and remain in different areas of the head and face region.

Conclusion

CBCT was effective in detecting and locating opaque objects, such as iron, glass, stone, asphalt, and tooth. However, it showed limited potential in detecting lucent objects such as wood. It can be concluded that the efficacy of CBCT in detecting opaque objects was acceptable, and only wooden objects were not detectable.

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