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Incidental Pathology and Anatomic Variations in Oral and Maxillofacial Cone-beam Computed Tomographic Scans

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ENK and MEP designed the study, author ENK managed the literature searches, collected data, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author TJO managed data collection, authors MLC and MEP managed writing of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To determine the occurrence of incidental pathological and anatomical findings in CBCT scans.
Study Design: Retrospective cross sectional descriptive study which was done at a private imaging center from 2010 to 2012.
Methodology: 97 CBCT scans of the oral and maxillofacial area were reviewed.
Results: Scans of the maxilla were the commonest 60 (62%) and only 37 (38%) were mandibular scans. There were 55 (57%) scans whose indication for imaging could be ascertained. These were used to study the incidental findings. Majority (36, 65%) of the examinations were done on female patients while 19 (35%) were for males. Most 32 (58%) of the scans were required for implant site

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assessment. There were incidental findings in 40 (73%) scans, 35 (64%) had pathologies while 9 (16%) had significant anatomical findings. The highest overall rate of incidental pathological finding was in the airway area (18, 33%), followed by dental (16, 29%), periapical (13, 24%), periodontal lesions (7, 13%) and foreign bodies (2, 4%). Scans with incidental anatomical findings included variations in root canal morphology (6, 11%), nerve foramina (2, 4%) and dental roots protruding into the maxillary antrum (2, 4%).

Conclusion: Various incidental findings in CBCT images are to be expected. Pathological findings were the commonest while airway findings were the majority. A thorough review of CBCT scans will ensure early diagnosis and management of incidental pathologies while a good documentation of significant anatomical variations will provide important pre-operative information.

Keywords: Cone-beam CT; incidental; maxillofacial; oral pathology.

1. INTRODUCTION

A number of Oral and Maxillofacial imaging modalities and techniques have been developed in order to assess various conditions and diseases that afflict the dental and cranio-maxillofacial tissues. They include intraoral and extraoral two-dimensional (2D) radiographic techniques. However, due to the inherent limitations of the 2D images, advanced imaging modalities such as computed tomography (CT), cone beam computed tomography (CBCT) and magnetic resonance imaging (MRI) have been developed, thus allowing soft tissue imaging, multiplanar and three-dimensional (3D) imaging. Nevertheless, limited accessibility and high cost of installation has constrained the use of CT and MRI in dentistry [1-3]. Cone beam computed tomography (CBCT) addresses these shortcomings and exposes patients to low levels of ionizing radiation as compared to CT [4]. Mozzo et al. [5] and Aral et al. [6] introduced this type of volumetric CT which is designed for evaluation of craniofacial bones and dental hard tissues. However, it lacks a soft tissue window hence hindering the assessment of head and neck malignancy [7,8]. Cone beam imaging has both radiodiagnostic and therapeutic potential and has been clinically applied in management of various conditions and diseases of the dental and maxillofacial area [3,7,9]. Scans often cover additional areas which are not indicated for investigation. Assessment of these areas has revealed significant incidental findings [10-13]. Further, the overall occurrence of incidental findings varies from one study to the other. Studies done at the University of Southern California and Turkey revealed a 24.6% [10] and 92.8% [11] respectively. While Pliska et al. [13] found 65.5% of incidental findings. Nonetheless, all the studies found that the majority of these findings were in the airway area, they included mucosal thickening, retention cyst, sinus polyps, deviation of the nasal septum and enlarged turbinate, nasal concha hypertrophy and bullous concha. Other findings included periapical radiolucency, impacted teeth, condensing osteitis, soft tissue calcification, bone lesions and dental developmental anomalies. In addition, the TMJ findings comprised of erosion of the condyle, osteophytes, bifid condyle, condylar deviation [10-15]. CBCT imaging has been available in Nairobi, Kenya for the last three years. However, there is hardly any documented data on the review of incidental findings in the maxillofacial area in the CBCT scans of a Kenyan population, hence the need for this study. The aim of this study was to retrospectively determine reasons for requesting the CBCT scans, location, nature and prevalence of incidental findings in the CBCT images.

2. MATERIALS AND METHODS

The study was conducted at Dental and Maxillofacial Imaging Centre (DAMIC) which was the only center in Nairobi that offered CBCT imaging. In addition, the center offers various digital imaging techniques including orthopantomograms, cephalograms, skull radiography and intraoral imaging. It is located in Nairobi the capital city of Kenya where the majority of the dental practitioners are based. The research was a retrospective cross-sectional descriptive study which involved analysis of CBCT scans of dental and maxillofacial patients. The sample included 97 CBCT scans that had been done from October 2010 to August 2012.

The scans were performed using a CS 9000C 3D System, manufactured by Carestream Dental (Kodak Dental Systems), it had a focused field of view (FOV). The CS 3D imaging software 3.2.9 was used to analyze the images which were reconstructed to obtain axial, sagittal and coronal views. Panoramic and 3D views were likewise reconstructed. Due to the small FOV, two or three images (volumes) were separately acquired and stitched together in order to cover a large part of the mandible or the maxilla. The scans of the mandible covered the alveolar region, the mandibular bone and a part of the ramus excluding the TMJ area while the scans of the maxilla covered the alveolar region, lower region of the sinuses and the nasal cavity.

Data was collected from the archived CBCT images and manual imaging request forms. The findings were classified into two broad categories namely, anatomical variations and incidental pathology. The diagnosis was made on the basis of descriptions presented by White et al. [2] and Farman et al. [16]. Missing teeth and anatomic variations of third molars were not included in the study.

Data was analyzed by descriptive statistics and the frequency of occurrence of each finding was calculated. Data was analysed using statistical packages for social sciences (SPSS) 13.0 (SPSS inc. Chicago, Illinois, USA). The Chi-square test was used to determine the association between key variables. The significance levels were at $\alpha=0.05$. The study was approved by Kenyatta National Hospital/University of Nairobi-Ethics and Research Committee (KNH/UON-ERC); Approval number, P279/05/2012. Authority to access the CBCT scans was granted by the director of DAMIC.

3. RESULTS

The study involved manually sorting out CBCT request forms from a bulk of 5,351 imaging request forms which had been received at DAMIC within the study period. Only 81 (1.5%) were for CBCT scans while the rest were for 2-dimensional radiographs (Fig. 1). A simultaneous search through the computer database retrieved a higher number of 97 CBCT examinations. The age of the patients was not indicated in most of the request forms. However,a review of the dentition revealed that the majority of the scans had a permanent dentition.

Only 55 (56.7%) scans had their indication clearly stated in their respective request forms hence they were used to study the incidental findings. Most (36, 65%) of the examinations were done on female patients while 19 (35%) were for males (Table 1). Scans of the maxilla were 31(56%), while 24 (44%) were of the mandible. Majority (32, 58%) were for implant site assessment (Fig. 2). Incidental findings were found in 40 (73%) scans, the majority were pathological findings 35 (64%) while 9 (16%) scans had structures with anatomical variations. Some scans had a combination of anatomical and pathological findings. There was no association between the presence of the pathological findings and the site. A chi-square test showed no statistical significance ($X2=3.422$ P value = 0.09). The airway had the highest rate of pathological findings. Other pathologies were observed in the dental, periapical and periodontal tissues as shown in (Table 1).

Dental findings comprised of 9 (16%) scans with pulp calcification, 6 (11%) had caries, 2 (4%) with retained roots while 3 (5%) scans had internal and/or external tooth resorption. Two scans had external resorption of apices of 38 and 32 (Fig. 3) while the third scan had internal resorption of 47. The teeth were associated with periapical radiolucency and widened periodontal ligament space. Periapical lesions comprised of radiolucent (10, 18%) and radiopaque (3, 5%) lesions while the main periodontal pathology observed was periodontal bone breakdown.

The maxillary scans were used to assess the airway structures. This included the maxillary antrum and the nasal area whose findings are presented in (Table 2). Pathology in the airway was observed in 18 (58%) scans (Figs. 4 and 5). Majority of the findings were located in the antrum while mucosal thickening (14, 45%) was the commonest finding (Fig. 4). There was no association between the presence of pathological findings in the airway and gender. A chi-square test showed no statistical significance ($X2$ =0.536, P value = 0.585).

Anatomical variations included taurodontism, lower right second molar with one canal, upper left second molar with fused roots and two pulp canals, lower first premolar with bifid apical root, upper first premolar with three pulp canals (Fig. 6) and variations of the mental foramen including a foramen opening at the crest of the alveolar ridge (Fig. 7) and double mental foramina (Fig. 8).

Table 1. Distribution of incidental findings involving the bone and dental tissues

Incidental finding	Scans (%)	Female (%)	Male (%)
Total scans	55 (100)	36 (65)	19 (35)
Normal findings	15 (27)	7 (13)	8 (15)
Anatomical variations	**8 (15)**	**7 (13)**	**1 (2)**
Root canal morphology	6 (11)	5 (9)	1 (2)
Nerve foramen	2 (4)	2 (4)	0 (0)
Pathological	**35 (64)**	**23(42)**	**12(22)**
Periapical	13 (24)	9 (16)	4 (7)
Dental	16 (29)	11(20)	5 (9)
Periodontal	7 (13)	6 (11)	1 (2)
Foreign body	1 (2)	1 (2)	0 (0)

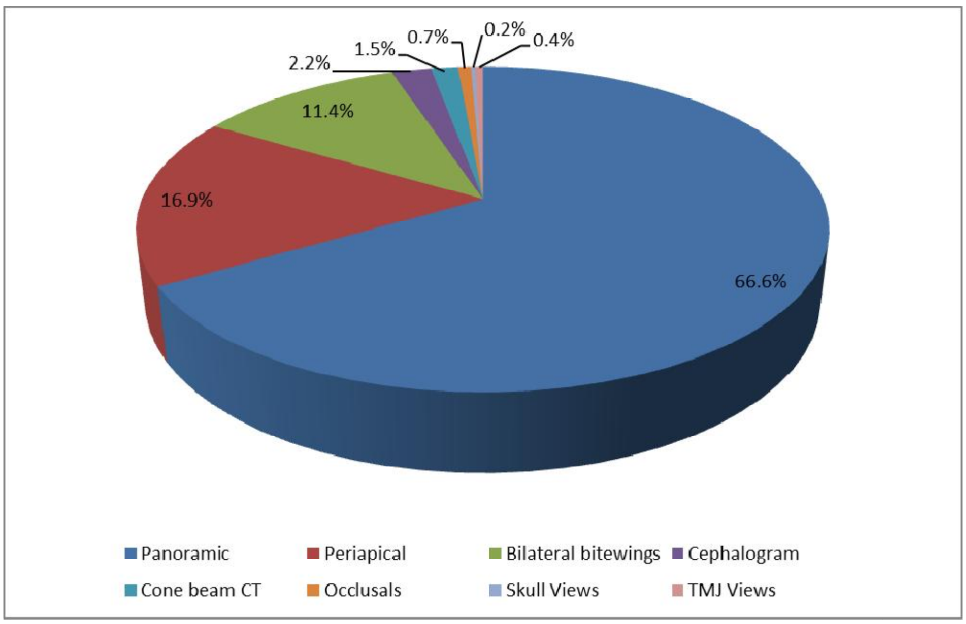

Fig. 1. Distribution of types of imaging examinations requested at DAMIC within the study period

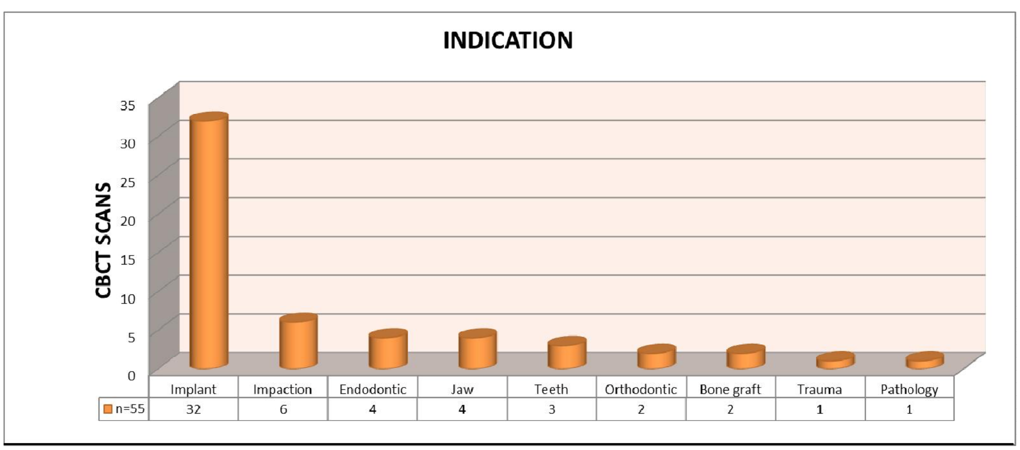

Fig. 2. Distribution of indications of CBCT scans

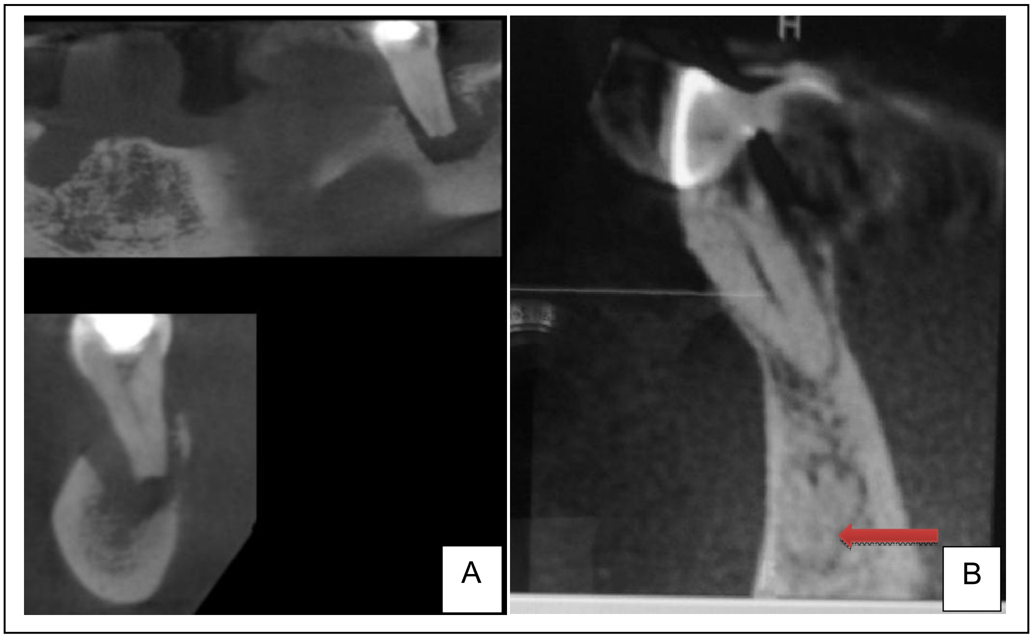

Fig. 3. Incidental findings of 38 and 33
(A) A panoramic and sagittal view showing a floating 38 with a radiopaque restoration, external root resorption, periodontal bone loss of the buccal, lingual, mesial and distal wall
(B) A sagittal view of 33 with radiopaque periapical pathology

Fig. 4. A panoramic view of the maxilla showing incidental mucosal thickening

Fig. 5. Axial view of the maxilla showing three stitched volumes and enlarged nasal turbinate

Fig. 6. Axial view of the maxilla showing three-rooted 15 and 25 (shown by the red arrows)

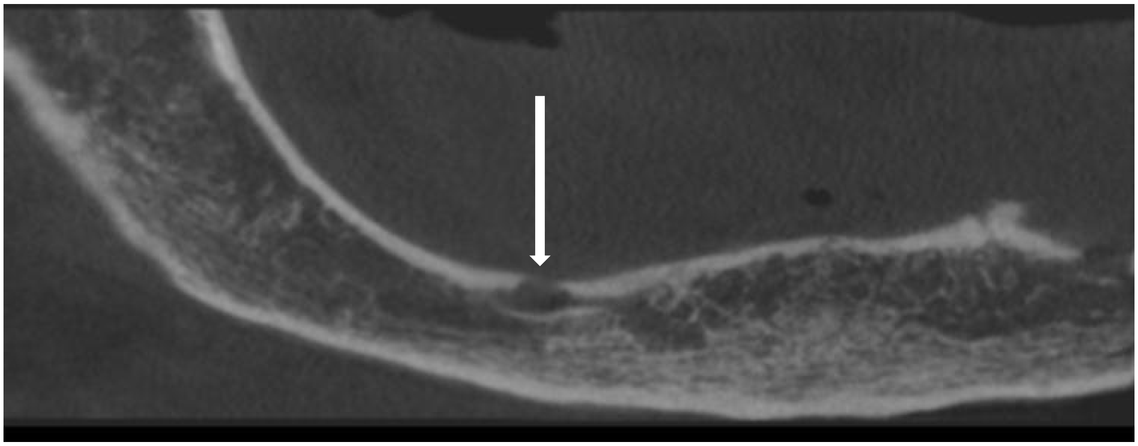

Fig. 7. A panoramic view of an edentulous mandible showing a mental foramen (shown by the white arrow) opening at the cortex of the alveolar ridge

Table 2. Airway incidental findings

Findings	Total scans (%)	Female (%)	Male (%)
Maxillary scans	31(100)	20 (65)	11(35)
No findings	11 (35)	9 (29)	2 (6)
Anatomical			
Roots protruding into the antrum	2 (6)	1 (3)	1 (3)
Pathological (Antrum)	16 (52)	9 (29)	7 (23)
Mucosal thickening	14 (45)	7 (23)	7 (23)
Polypoid lesions	5 (16)	2 (6)	3 (10)
Opacified antrum	1 (3)	1 (3)	1 (3)
Foreign body	1 (3)	1 (3)	0 (0)
Pathological (Nasal area)	3 (10)	2 (6)	1 (3)
Concha hypertrophy	3 (10)	2 (6)	1 (3)
Deviated septum	1 (3)	1 (3)	0 (0)
Total airway pathological findings (antrum and nasal area)	18 (58)	10 (32)	8 (26)

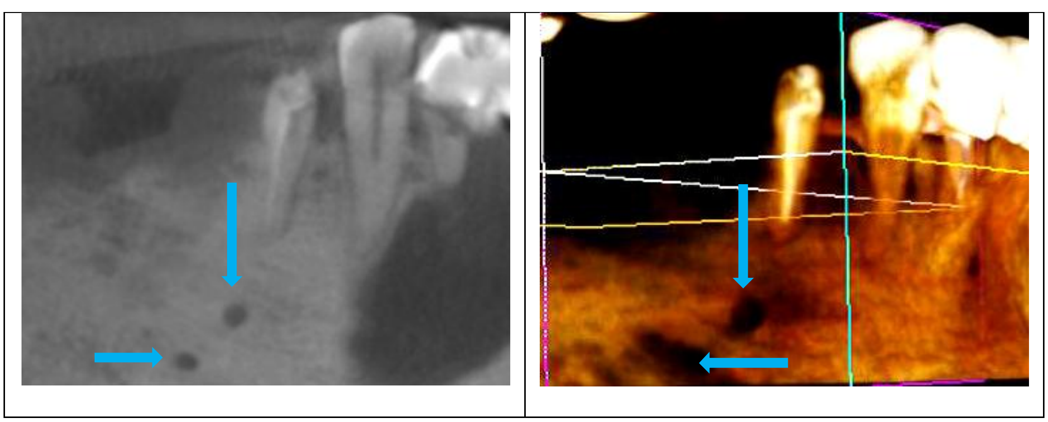

Fig. 8. A panoramic view and 3D reformatting of the same patient showing double mental foramina (shown by the blue arrows)

4. DISCUSSION

Cone beam CT is still a new technology in Kenya as depicted by the low number of scans requested over the study period. This could be due to a low level of awareness and attitude towards CBCT imaging among dental practitioners as well as cost implicationsand limitations related to the small FOV of the available CBCT scanner. However, the utilization of CBCT is likely to increase as has been noted in the developed countries where more dental surgeons are installing the equipment owing to its numerous benefits, low cost and small footprint compared to conventional CT [3,4]. The study revealed that the commonestindication for CBCT wasfor implant site assessment similar to a study by Ritter et al. [15]. However, CBCT imaging has numerous clinical applications and a different study done in an orthodontic department found orthodontic reasons to have been the majority (50%) followed by implantology (34%) [10]. While, a Turkish [11] study found that most (41%) scans were indicated for TMJ disorders and only 7% for implant purposes. In our study CBCT for other purposes were minimally requested.

Despite the small FOV, evaluation of the CBCT scans revealed various pathological incidental findings which were consistent with previous studies [10,11,12,13]. Past studies have shown a varying overall rate of incidental findings. In two studies a high overall rate of 92.8% (192/207) [11] and 90.7% (272/300) [12] were found, while Pliska et al. [13] observed a rate of 65.5% (127/194) which is almost similar to the present study. Cha et al. [10] found a lower overall rate of 24.6% (123/500). The difference in the overall rate of findings could be due to variations in the study population in regard to age, gender and race, inclusion criteria of incidental findings, FOV of the CBCT scanners and performed examination. The preceding studies had particularly larger sample sizes and images were taken from CBCT machines with larger FOV. The present study included findings such as periodontal bone loss, caries, pulp calcification and tooth resorption which were not included in most of the earlier studies. For reasons of clarity, lesions in this study were grouped according to location such as dental, periapical or periodontal tissues while the previous studies grouped lesions involving periapical tissues and teeth as endodontic lesions. Nonetheless, similar to previous studies, the highest rate of incidental findings was found in the airway area.

Findings in the dental tissues comprised of caries, resorption, pulp stones, and retained roots. Secondary caries was easily diagnosed as it was possible to assess the teeth in multiple planes unlike in plain radiographs where such caries can be obscured by radiopaque restorations. However, it was difficult to diagnose caries on some scans due to streak artifacts and beam hardening effect of restorations, prosthesis and orthodontic appliances. Nevertheless, CBCT imaging has been found to suffer from less disturbance from metal artifacts compared to conventional CT. Further, incorporation of artifact suppression algorithms and use of CBCT scanners with flat panel detectors has been found to reduce the level of metal artifact [9,17]. In a study that compared depth measurements of proximal caries using various imaging modalities (CBCT, phosphor plate, F-speed film) and a gold standard (histological sectioning), CBCT agreed very closely with the gold standard. Hence, CBCT can contribute significantly to early diagnosis and monitoring of caries [18]. However, it should not be the preferred technique for the routinediagnosis of caries.

Pathological tooth resorption may be initiated by trauma, chronic infection, tooth reimplantation, local contact with cysts, tumours and impacted teeth as well as dental procedures such as pulpotomy, pulp capping and excessive orthodontic forces or it may be idiopathic. External resorption is common, involves either the cervical or apical region of the teeth and affects mandibular more than the maxillary teeth [2]. Tooth resorption is often asymptomatic and may be an incidental radiographic finding. Early diagnosis is paramount since excessive resorption may weaken the tooth leading to tooth loss. If identified early, management of internal resorption may involve root canal therapy whereas external root resorption is managed through the removal of etiologic factors and restoration of the accessible root defect [2,19]. Studies show that 3-D imaging considerably increases the detection of resorption of the roots of incisors adjacent to ectopically erupting maxillary canines by about 50% as compared to intraoral radiographs [20].

The calcification that was observed in the pulp chamber and canals is likely to be pulp stones or pulp sclerosis. Pulp stones are foci of calcification while pulpal sclerosis is a diffuse process which increases with age. Pulp stones are a common radiographic finding but most are microscopic and the larger masses represent only 15 – 25%. Pulpal calcifications do not require any treatment but dentists need to be aware of their existence since they can cause difficulty during endodontic therapy [2,16].

Periapical lesions ranged from slight widening of the apical periodontal ligament space to large radiolucent and radiopaque lesions. The largest lesion was 14.3 x 9.9 mm. CBCT imaging has been found to be more valuable in detecting periapical lesions compared to 2D imaging. A study that compared the two techniques demonstrated 53 lesions in periapical radiographs but 86 lesions were found when CBCT images of the same teeth were reviewed, resulting in 62% more lesions being detected[21]. Differentialdiagnosis of common radiolucent periapical lesions includes inflammatory lesions (apical periodontitis, apical abscess and periapical granuloma), radicular cyst, early stages of periapical cemental dysplasia or a surgical defect. In rare cases metastatic lesions and malignancies may occur in the periapical region [2,16]. A few periapical lesions were radiopaque, these could have been osteosclerosis, condensing osteitis, late stages of periapical cemental dysplasia or tumours. Complete diagnosis of these lesions requires a combination of the clinical signs and symptoms, tooth vitality test and histopathological examination where applicable [1,16]. Further, measurement of the grey scale value of the periapical lesions on CBCT images has been shown to give a clear distinction between a cyst and a granuloma [22].

Obvious periodontal breakdown was identified in 13% of the scans. It consisted of furcation bone involvement, horizontal and vertical bone loss. Whereas horizontal bone loss, interproximal crater and furcation involvement are easily identified on 2D images, infrabony defects involving buccal and lingual cortical plates are often difficult to identify. With CBCT it is possible to clearly demonstrate the presence and depth of such defects without superimposition of either of the cortical bony plates which is very important in treatment planning [2,16,23]. Vandenberghe et al. [24] compared 2D digital intraoral radiographs with 3D CBCT images in assessing periodontal breakdown. Cone beam CT was found to be superior in assessing crater defects and furcation involvements. However, intraoral radiography provided more bone details such as contrast, bone quality, and delineation of lamina dura.

About half of the patients who had maxillary scans had pathology in the antrum. This corresponds to previous CBCT studies which revealed a prevalence of 56.3% 25 and 50% [25]. Mucosal thickening of the antrum wall was the commonest finding in the present study. The thickness of the mucosa ranged from 2 mm - 23 mm. Such mucosal lining that is more than 3mm thick is thought to be pathologic due to an infection or allergic reaction [2]. Similarly, other CBCT studies found mucosal thickening to have been the most frequent finding in the airway [11, 15]. However, these studies found 31.8% [11] and 38.1% [15]which were low compared to the present study. The difference could be due to the variation in the study population. An evaluation of MRI images for the prevalence of sinusitis found 40% abnormal images of the maxillary sinus [26] whereas a 2D panoramic study found quite a low (12%) prevalence of mucosal thickening in the antrum [27]. This could have been due to poor visualization of the antrum in 2D images because of the superimposition of structures. However, mucosal thickening was still the most common finding. Patients with such pathological findings that are suggestive of sinusitis should be followed up to find out if they have a related medical history as well as assessment for further investigation and/or referral for management of significant findings. However, Cha et al. [10] found a weak relationship between the incidental airway findings and related medical history. Only 22% of the orthodontic patients with incidental airway findings suffered from allergies, asthma or sinusitis [10]. Dental pathology involving periapical and periodontal tissues has also been found to play a significant role in the development of mucosal thickening [27]. Moreover, foreign bodies such as dental materials could be dislodged into the antrum and may cause mucosal inflammation.

Polypoid lesions that were observed in the current study were noncorticated, smooth radiopaque masses. A previous study that reviewed 500 CBCT scans for dental implants revealed a slightly higher incidence of 21.4% [14] while a study involving 1,029 CBCT scans revealed a lower incidence of 7% [15]. These lesions may represent mucous retention cysts or antral polyps. A maxillary antrum that manifests polypoid lesions should be clearly examined so as to rule out odontogenic cysts and neoplasms of the antrum [2].

The presence of root tips projecting into the antrum was observed in a few maxillary scans. Such anatomic relation should be noted since extraction of these teeth may lead to oroantral fistula or displacement of roots into the antrum [28,29]. Cone Beam CT imaging could play a significant role in management of teeth that are in close proximity to the antral floor [30]. In the view of these findings radiographic evaluation of the sinus by dental surgeons is inevitable. The ability to easily identify pathological changes in the antrum continues to demonstrate that CBCT could be applied in evaluation of the maxillary sinus due to its numerous benefits as compared to CT and plain film radiography.

Other than the protrusion of tooth roots into the floor of the antrum, other incidental anatomical findings comprised of variations in dental roots and pulp canal morphology as well as nerve foramina. The complex configuration of pulp canal morphology has been well described by Vertuccci [31,32]. Cone beam CT can play a remarkable role in revealing such complexity which is a prerequisite for successful root canal therapy.

Further, anatomical variation in the position and number of the mental foramina was observed in this study. In two scans of edentulous mandible, the mental foramina were located at the crest of the residual alveolar ridge. This may have been caused by severe resorption. The exposed mental nerve is usually sensitive to pressure hence it should be taken into consideration when fabricating dentures. Relieving of the denture and stabilization of the dentures with implants has been done to make such patients comfortable [33]. Double mental foramina were observed in one scan. Previousstudies have shown anincidence of 2 – 7% as well as further variability in itsposition, shape, sizeand presence of accessory canals. The preoperative radiological examination of the mental foramen can play a vital role in successful administration of local anaesthesia. In addition, it can preventdamage to the neurovascular bundle during surgical procedures and root canaltreatment of the lower premolars and molars which may lead to paraesthesia or anaesthesia [34-37].

It is evident that CBCT scans provide very variable information; therefore, they should be thoroughly evaluated. In Kenya where there is only one maxillofacial radiologist who may not always be available to interpret the increasing number of dental images, dental practitioners should also endeavor to acquire radiological skills on CBCT imaging as has been recommended by the American Academy of Oral and Maxillofacial Radiology Executive Committee [38]. As the number of CBCT examinations increase in Kenya, a furtherstudy with a larger sample size is recommended in order to verify the association between the presence of the pathological findings and factors such as site and gender which were found to be statistically insignificant in this study.

5. CONCLUSION

Various incidental findings in CBCT images are to be expected. There were pathological and anatomical findings in the majority of the scans. Pathologies were the commonest while airway pathological findings were the majority. A thorough review of CBCT scans will ensure early diagnosis and management of incidental pathology while a good documentation of significant anatomical variations will provide valuable preoperative information.

CONSENT

Not applicable.

ETHICAL APPROVAL

All authors hereby declare that all necessary ethical approval has been obtained from Kenyatta National Hospital/University of Nairobi-Ethics and Research Committee (KNH/UON-ERC); Approval number, P279/05/2012.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Whaites E. editor. Radiography. In: Essentials of dental radiography and radiology, 3rd ed. London: Churchill Livingstone; 1996.

2. White SC, Pharoah MJ. Oral Radiology: Principles and interpretation, 5th ed, Mosby Company, St Louis; 2004.
3. White SC. Cone-beam imaging in dentistry. Health Phys. 2008;95:628-637.
4. Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;106:106-114.
5. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis A. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol. 1998;8:1558–1564.
6. Arai Y, Tammisalo E, Iwai K, Hashimoto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. Dentomaxillofac Radiol. 1999;28:245–248.
7. Macleod I, Heath N. Cone-Beam Computed Tomography (CBCT) in Dental Practice. Dent Update 2008;35:590-598.
8. Cohnen M, kemper J, Mobes O, Pawelzik J, Modder U. Radiation dose in dental radiology. Eur Radiol. 2002;12:634-637.
9. Scarfe WC, Farman AG, Sukovic P. Clinical application of conebeam computed tomography in dental practice. J Can Dent Assoc. 2006;72:75-80.
10. Cha JY, Mah J, Sinclair P. Incidental findings in the maxillofacial area with 3-Dimensional cone-beam imaging. Am J Orthod Dentofacial Orthop. 2007;132:7-14.
11. Caglayan F, Tozoglu U. Incidental findings in the maxillofacial region detected by cone beam CT. Diagn and Interv Radiol. 2012;18:159-163.
12. Price JB, Thaw KL, Tyndal AD, Ludlow BJ, Padilla RJ. Incidental findings from cone beam computed tomography of the maxillofacial region. Clin Oral Implants Res. 2012;23:1261-1268.
13. Pliska B, DeRocher M, Larson BE. Incidence of significant findings on CBCT scans of an orthodontic patient population. Northwest Dent. 2011;90:12-16.
14. Lana JP, Carneiro PMR, Machado VC, de Souza PEA, Manzi FR, Horta MCR. Anatomic variations and lesions of the maxillary sinus detected in cone beam computed tomography for dental implants. Clin. Oral Imp. Res. 2012;23:1398-1403.
15. Ritter L, Lutz J, Neugebauer J, Scheer M, Dreiseidler T, Zinser MJ, et al. Prevalence of pathologic findings in the maxillary sinus in cone-beam computerized tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;111:634-640.
16. Farman AG, Nortjé CJ, Wood RE, editors. Oral and maxillofacial diagnostic imaging. Missouri: Mosby. 1993;181-400.
17. De Vos W, Casselman J, Swennen GRJ. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: A systemic review of the literature. Int. J. Oral Maxillofac. Surg. 2009;38:609-625.
18. Akdeniz BG, Grondahl HG. Magnusson B. Accuracy of proximal caries depth measurements: comparison between limited cone beam tomography, storage phosphor and film radiography. Caries Res. 2006;40:202-207.
19. Sikri VK. Fundamentals of dental radiology, 3rd Ed, Satishkumar Jain, CBS Publishers, New Delhi. 2006;51-177.
20. Ericson S, Kurol J. Resorption of incisors after ectopic eruption of maxillary canines: a CT study. Angle Orthod. 2000;70:415-423.
21. Lofthag-Hansen S, Huumonen S, Gro¨ ndahl K, Gro¨ ndahl H-G. Limited cone-beam CT and intraoral radiography for the diagnosis of periapical pathology. Oral Surg, Oral Med, Oral Pathol, Oral Radiol and Endod. 2007;103:114–119.
22. Simon JHS, Enciso R, Malfaz JM, Roges R, Bailey-Perry M, Patel A. Differential diagnosis of large periapical lesions using cone-beam computed tomography measurements and biopsy. J Endod. 2006;32:833–837.
23. Misch KA, Yi ES, Sarment DP. Accuracy of cone beam computed tomography for periodontal defect measurements. J Periodontol. 2006;77:1261-1266.
24. Vandenberghe B, Jacobs R, Yang J. Diagnostic validity (or acuity) of 2D CCD versus 3D CBCT-images for assessing periodontal breakdown. Oral Surg, Oral Med, Oral Pathol, Oral Radiol Endod. 2007;104:395–401.
25. Smith KD, Edwards PC, Saini TS, Norton NS. The prevalence of concha bullosa and nasal septal deviation and their relationship to maxillary sinusitis by volumetric tomography. Int J Dent. 2010;2010: 404982. Epub 2010 Aug 24 doi:10.1155/2010/404982.
26. Gordts F, Clement PA, Buisseret T. Prevalence of sinusitis signs in a non-ENT population. ORL J Otorhinolaryngol Relat Spec. 1996;58:315-319.

27. Vallo J, Suominen-Taipale L, Huumonen S, Soikkonen K, Norblad A. Prevalence of mucosal abnormalities of the maxillary sinus and their relationship to dental disease in panoramic radiography: results from the Health 2000 Health Examination Survey. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010;109:80-87.
28. Yalçın S, Oncü B, Emes Y, Atalay B, Aktaş I. Surgical treatment of oroantral fistulas: a clinical study of 23 cases. J Oral Maxillofac Surg. 2011;69(2):333-339.
29. Guven O. A clinical study on oroantral fistulae. J Craniomaxillofac Surg. 1998;26:267-271.
30. Patel S, Dawood A, Ford TP, Whaites E. The potential applications of cone beam tomography in the management of endodontic problems. Int Endo J. 2007;40:818-830.
31. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg, Oral med, Oral path. 1984;58:589-599.
32. Harty's endodontics in clinical practice. Pulp space anatomy and access cavities Pitt F.T.R 5th Ed 2004 Butterworth-Heinemann. 2004;17-33.
33. Zarb GA, Bolender CL, Eckert SE, Jacob RF, Fenton AH, Mericske-stern R, editors. Prosthodontic treatment for edentulous patients. Missouri: Mosby. 2004;73-99.
34. Ilayperuma I, Nanayakkara G, Palahepitiya N. Morphometric analysis of the mental foramen in Adult Sri Lankan Mandibles. Int. J. Morpho. 2009;27:1019-1024.
35. Fabian FM. Position, shape and direction of opening of the mental foramen in dry mandibles of Tanzanian adult black males. Ital J Anat Embryol. 2007;112(3):169-177.
36. Sankar DK, Bhanu SP, Susan PJ. Morphometric and morphological study of mental foramen in dry dentulous mandibles of South Andhara population of India. Indian J Dent Res. 2011;22:542-546.
37. Naitoh M, Hiraiwa Y, Aimiya H, Gotoh K, Ariji E. Accessory mental foramen assessment using cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:289-294.
38. Farman AG. American Academy of Oral and Maxillofacial Radiology executive opinion statement on performing and interpreting diagnostic cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008;106(4)561-562.

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