AMERICAN COLLEGE OF PROSTHODONTISTS
Your smile. Our specialty.®

Incidental Findings in Cone Beam Computed Tomography for Dental Implants in 1002 Patients

Mamdouh O. Kachlan, BS,[1] Jie Yang, DDS, MS,[2] Thomas J. Balshi, DDS, PhD, FACP,[3] Glenn J. Wolfinger, DMD, FACP,[4] & Stephen F. Balshi, MBE[5]

[1]Temple University Kornberg School of Dentistry, Philadelphia, PA
[2]Department of Oral Pathology, Medicine, & Surgery, Temple University Kornberg School of Dentistry, Philadelphia, PA
[3]Department of Prosthodontics, Nova Southeastern University College of Dental Medicine, Fort Lauderdale, FL
[4]Prosthodontist, Pi Dental Center, Fort Washington, PA
[5]Biomedical Engineering & Research, Pi Dental Center, Fort Washington, PA

Keywords
Cone-beam computed tomography; radiology; pathology.

Correspondence
Stephen F. Balshi, M.B.E. Pi Dental Center 467 Pennsylvania Ave Suite 201 Fort Washington, PA 19034. E-mail: stephen.balshi@cmprosthetics.com

Disclosure: The authors report no conflicts of interest.

Accepted January 7, 2021

doi: 10.1111/jopr.13329

Abstract

Purpose: The purpose of this study is to analyze the frequency and elevate the awareness of the prevalence of nondental pathology in cone beam computed tomography (CBCT) scans taken for implant placement treatment planning and postplacement evaluation. The data from the CBCT should be read by an oral and maxillofacial radiologist for proper diagnosis of dental and nondental pathology and referred to the medical specialist for proper management when necessary.
Materials and methods: This retrospective study analyzed 1002 consecutive CBCT scans taken at a single private practice noting the prevalence of nondental pathology in CBCT images for all dental implant procedures. All scans were taken from November 2007 to March 2020. One board certified oral and maxillofacial radiologist systemically read all scans and reported all findings in the maxilla and mandible, condyles and TMJ, paranasal sinuses, nasal fossa, pharyngeal airway, skull base and temporal bone, neck soft tissues, and cervical spine. The incidental findings, variation of normal anatomy, or pathology reported in these structures were categorized based on anatomic location and significance and the incidence was investigated.
Results: Pathologies ranged from innocuous sinusitis, to more serious atherosclerotic calcification of the carotid arteries, narrowed airways, and neoplastic lesions. Fifty-one different findings were noted, of which 36 were pathologies that required referral or follow-up.
Conclusions: Incidental findings can be detected in CBCT scans for dental implants. The clinician must be familiar with the radiographic diagnosis of head and neck pathology, and/or must refer these images to an appropriate specialist for the radiographic interpretation of the full volume.

The use of cone beam computed tomography (CBCT) in implantology, oral surgery, periodontology, orthodontics, and endodontics has greatly improved treatment success.[1–7] CBCT is the scan of choice for implant treatment planning as it offers greater measurement accuracy at lower radiation dosage, reduced scan time, and reduced artifacts compared to 2D and conventional medical CT imaging.[8–13] Failure to use CBCT can result in inadequate treatment planning with a less predictable prognosis.[14] CBCT has been advocated for ideal implant orientation,[15–19] and to locate vital structures such as the antrum, the orbit, inferior alveolar nerve, mental foramen, anterior loop, and sinus septa.[20]

The American Academy of Oral and Maxillofacial Radiology (AAOMR) holds the position that CBCT volumes, regardless of clinical application, should be systematically evaluated for signs of abnormalities.[21] The prevalence of incidental findings in radiographic imaging is high and differs within studies based on sample size and population demographics.[22,23] In the jaws, CBCT can identify findings such as osteosclerosis, periapical pathology, odontogenic and nonodontogenic cysts, and malignant tumors. In the paranasal sinuses, it can identify mucosal thickening, blocked ostiomeatal complex, airway obstruction, antral communication, antral polyps, retention pseudocysts, nasal polyposis, deviated nasal septum, concha bullosa, tonsillar hypertrophy, and tonsilloliths. In the condyles, CBCT can show joint remodeling, degenerative joint disease, condylar hyperplasia, and bifid condyle. In the skull base, it can show pineal gland calcification, pituitary gland

Table 1 Categorization and reported prevalence of incidental findings of high potential clinical significance on CBCT according to anatomic location

Location	Entity	Total count	Percent of total patients
Jaws	Cysts/benign tumors	6	0.60
	Osteomyelitis/Osteonecrosis	5	0.50
	Malignant tumors	3	0.30
	Soft tissue mass/tumor	3	0.30
	Leukemia could not be ruled out	1	0.10
Nasal fossa/maxillary sinus	Soft tissue mass/tumor	2	0.20
	Anterior nasal septal defect. Clinical correlation is indicated to rule out Wegeners granulomatosis or substance use.	1	0.10
Skull base/neck	Atherosclerotic calcifications of the carotid arteries	176	17.56
Neck	Soft tissue mass/tumor	2	0.20
Brain	Pituitary gland calcification	1	0.10
Temporal bone/ear	Cholesteatoma	4	0.40
Cervical Spine	Vertebral body factures of C6 (severe), C7, and T1	1	0.10
Other	Multiple myeloma	1	0.10
	Rheumatoid arthritis	1	0.10
	Calcifications/proliferations requiring follow-up or clinical correlation	10	1

calcification, and intracranial calcified carotid artery atheromas. In the cervical spine, it can show degenerative changes of the cervical spine and herniation of intervertebral disc. In the neck, it can reveal stylohyoid ligament calcification, calcified thyroid/triticeous cartilage, and extracranial calcified carotid artery atheromas. It can also show fractures and proptosis.

Materials and methods

All one thousand two consecutive patients in a single private practice that had a CBCT scan taken from November 2007 to March 2020 were included in this retrospective study. Images were initially taken using the iCAT imaging system (Imaging Sciences International, Hatfield, PA) until December 2017. The field of view was 22 cm in height and the width of the sensor is 16 cm. Subsequently, the Vatech Green CT PAX i3D (Vatech Co., Ltd., Hwaesong-Si, Korea) was used from December 2017 until March 2020 using the configuration 95KVP 5.7MA 150 mm × 150 mm (Diameter × Height).

CBCT scans were taken for three reasons: (1) digital treatment planning for implant placement, (2) further evaluation of a finding from conventional panoramic and cephalometric radiographs, or (3) postoperative follow up care as needed

The CBCT images were reviewed by the authors on computer screens with Anatomage Invivo software (Anatomage US, Santa Clara, CA) or i-CAT Vision Software (Imaging Sciences International, Hatfield, PA). A standardized report was generated by the oral maxillofacial radiologist for each scan, with an analysis of visible head and neck pathology. From these radiology reports, data was reviewed for this study. Patients with serious pathology requiring further medical attention were referred to the appropriate medical specialist. None of the reports from the radiologist were excluded from this study. Dental-specific data (ex: atrophic maxilla or mandible, missing teeth, root fractures, etc.) was excluded from the analysis as it can be seen in 2D imaging. The findings are organized into Tables 1, 2, and 3 based on significance and anatomic location. The significance is classified into low, intermediate, and high. Low significance is incidental and does not require follow up or intervention. Intermediate significance can require follow-up, or referral. High significance requires immediate medical intervention.

Results

One thousand two CBCT scan reports were retrospectively reviewed between November 2007 and March 2020. Male patients constituted 406 (40.52%) and female patients constituted 596 (59.48%) of the sample. Fifty-one different nondental findings were noted, the details of which are reported in Tables 1, 2, and 3.

The most common finding was inflammatory sinus disease (mucositis or sinusitis, 52.39%), followed by degenerative changes of TMJs (39.92%), narrowing of the airway (18.96%), atherosclerotic calcifications of the arteries (17.56%),

Table 2 Categorization and reported prevalence of incidental findings of intermediate potential clinical significance on CBCT according to anatomic location

Location	Entity	Total count	Percent of total patients
Jaws	Osteoporosis or enlarged marrow spaces	2	0.20
	Cemento-osseous lesion	4	0.40
	Periapical pathology (apical periodontitis, condensing osteitis, root resorption, hypercementosis)	35	3.49
Paranasal sinuses	Sinusitis	525	52.39
	Rhinitis/nasal polyposis	43	4.29
	Antral polyps	10	1
Pharyngeal airway	Narrowing of the airway	190	18.96
	Discontinuity of sinus floor/antro-oral fistula	6	0.60
TMJ	Degenerative changes of TMJs	400	39.92
	Hyperplasia	2	0.20
	Previous condyle fracture	2	0.20
	Mandibular/Maxillary fracture	2	0.20
	Subluxation of the left condyle	1	0.10
Cervical spine	Degenerative changes of C-spine	151	15.01
	Herniation of an intervertebral disc	1	0.10
	Nonsegmentation of C2-3	1	0.10
Neck soft tissues	Sialoliths	5	0.50
Other	There were inflammatory changes of the right orbit	2	0.20
	Proptosis	1	0.10
	There was new bone formation in the lateral wall of the left maxillary sinus near the zygomatic	1	0.10
	Multiple linear calcifications in the left orbit	1	0.10

Table 3 Categorization and reported prevalence of incidental findings of low potential clinical significance on CBCT according to anatomic location

Location	Entity	Total count	Percent of total patients
Jaws	Enostosis/osteosclerosis	9	0.90
Paranasal sinuses	Retention pseudocysts	43	4.29
Nasal fossa	Deviated nasal septum	100	9.98
	Conchae bullosa	16	1.59
	Rhinitis/nasal polyposis	43	4.29
Pharyngeal airway	Tonsillar hypertrophy	19	1.89
	Tonsilloliths	56	5.59
TMJ	Remodeling	92	9.18
	Bifid condyle	5	0.50
Skull base/brain	Pineal gland calcification	7	0.70
Neck soft tissues	Stylohyoid ligament calcification	1	0.10
	Calcified thyroid cartilage/triticeous cartilage	3	0.30
Other	Calcification of ligament of the left lateral pterygoid muscle (incidental)	1	0.10
	Laryngeal cartilage calcification	2	0.20
	Fullness of vallecula	1	0.10

degenerative changes of the cervical spine (15.01%), deviated nasal septum (9.98%), remodeling of the TMJs (9.18%), tonsillolith (5.59%), rhinitis/nasal polyps and retention pseudocyst both were (4.29%), benign lesions (1.7%), and malignant lesions (0.3%). Figures 1–5 are provided for illustration and are similarly classified based on significance and anatomic location. Figure 1 shows findings of high significance that require patient follow up with medical specialists. These include multiple myeloma, calcifications of the carotid arteries in the base of the skull and the neck, odontogenic tumor, and a calcification in the sella turcica that turned out to be a tumor (craniopharyngioma). Figure 2 explores findings of intermediate significance related to erosion, destruction of condyles, and degenerative joint disease. Figure 3 shows findings of intermediate significance in the sinus and airway, such as mucosal thickening, mucous retention cysts, and narrowed airways. Figure 4 shows findings of intermediate significance such as degenerative changes of the cervical

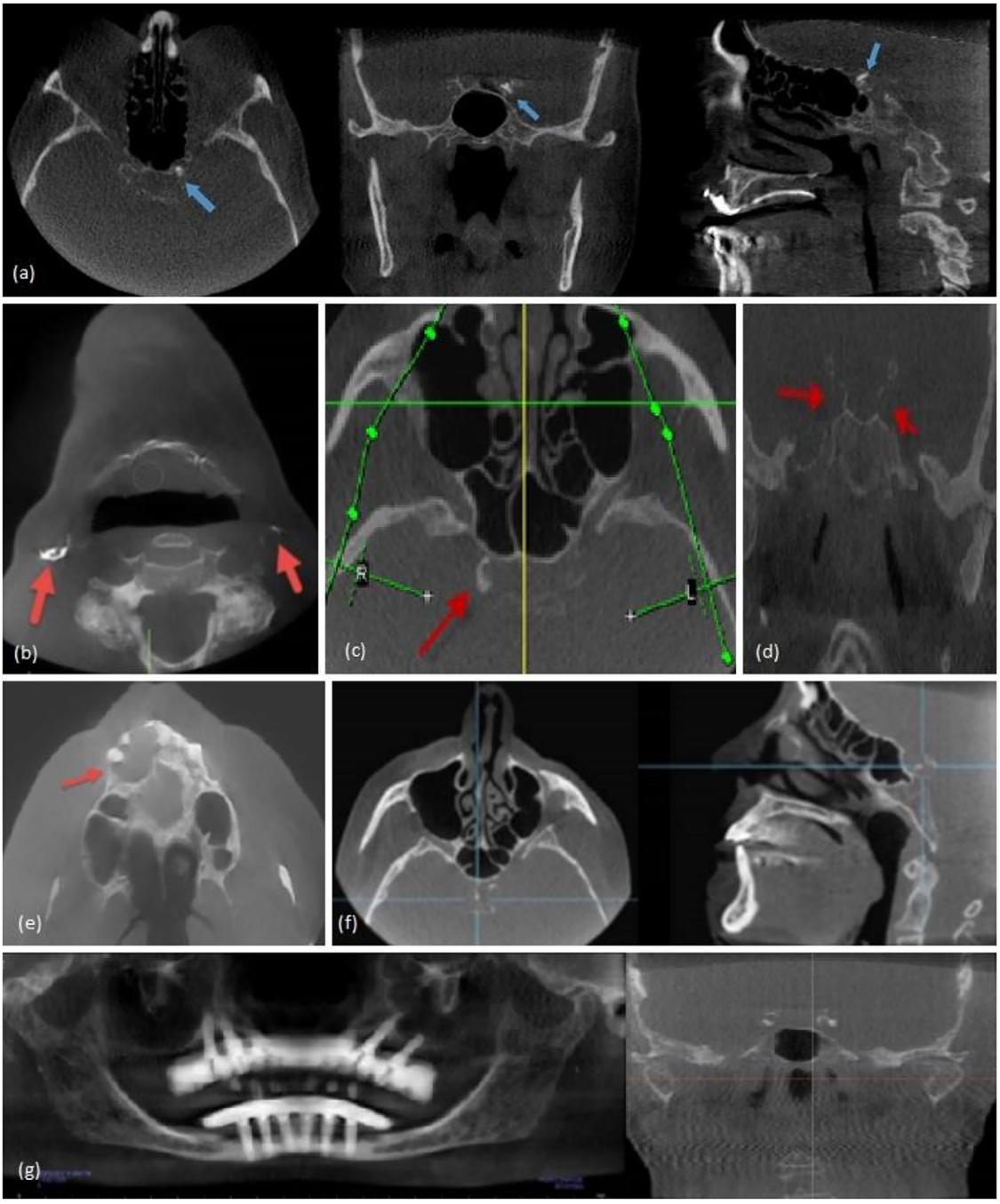

Figure 1 Findings of high significance: (A) intracranial calcification of the carotid artery on axial, coronal, and sagittal views; (B) thick carotid calcifications in the neck; (C) carotid calcification in the right skull base; (D) carotid calcifications at the cavernous portions of the carotid arteries; (E) radiographically suspected an odonotogenic cyst or tumor with external root resorption and buccal expansion. Biopsy showed granulation tissue with abscess and bacterial colonies consistent with morphology of actinomyces; (F) tumor (craniopharyngioma) calcification in the sella turcica. The sagittal view shows partial resorption of the dorsum sella; and (G) punched out radiolucent areas in the mandible, other facial bones, and cervical spine. The appearances are consistent with multiple myeloma.

spine, osteolytic areas in the cervical spine, subluxation of the condyle, and fracture in the maxilla. Figure 5 shows findings of low significance such as enlarged palatal tonsil and adenoidal hyperplasia, which are common in children.

Discussion

When 3D planning for implant placement is performed, all critical anatomic structures are considered in the development of

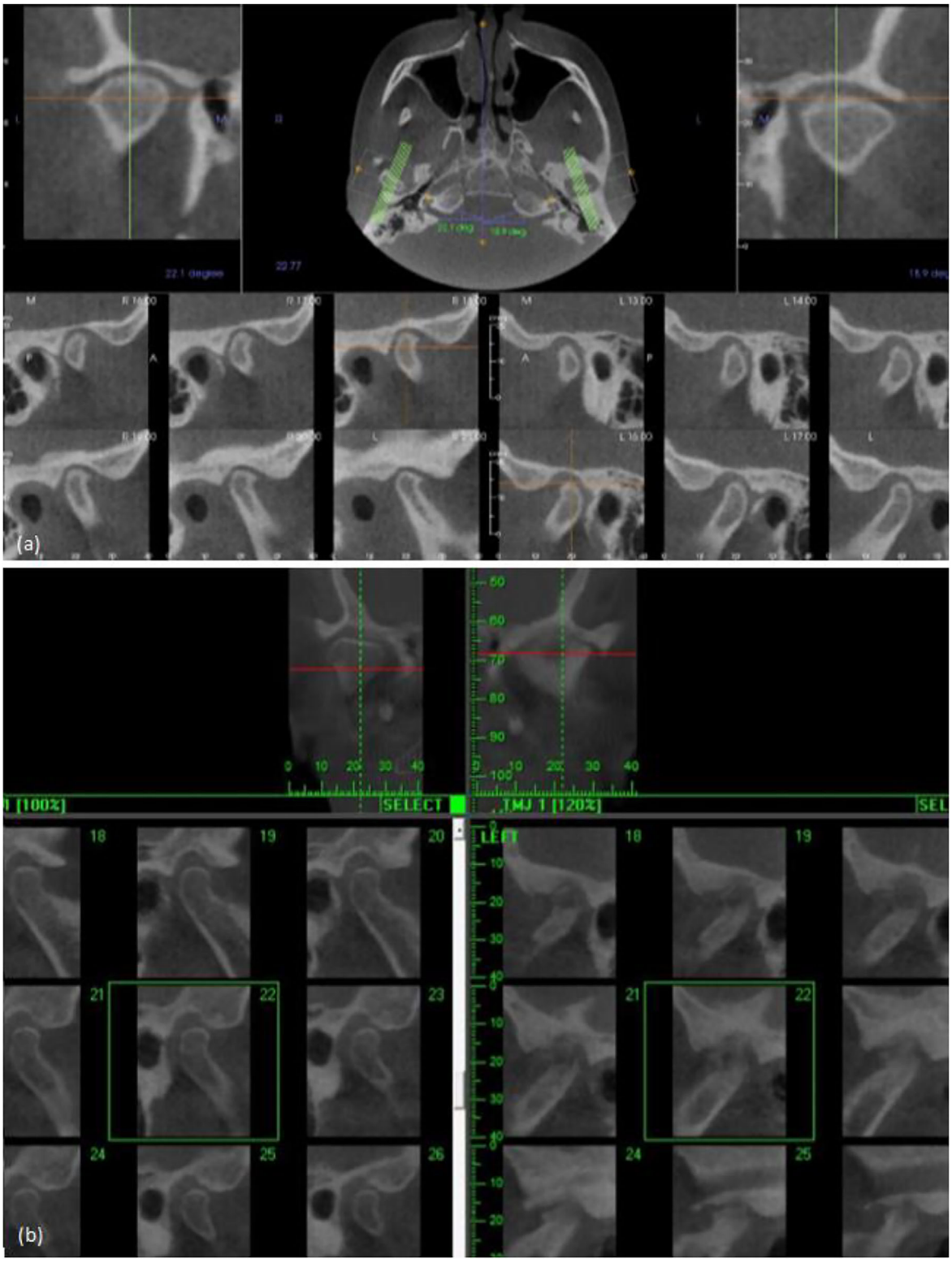

Figure 2 Findings of intermediate significance in the temporomandibular joint: (A) degenerative joint disease and remodeling; (B) considerable bone erosion, destruction of the left condyle and glenoid fossa.

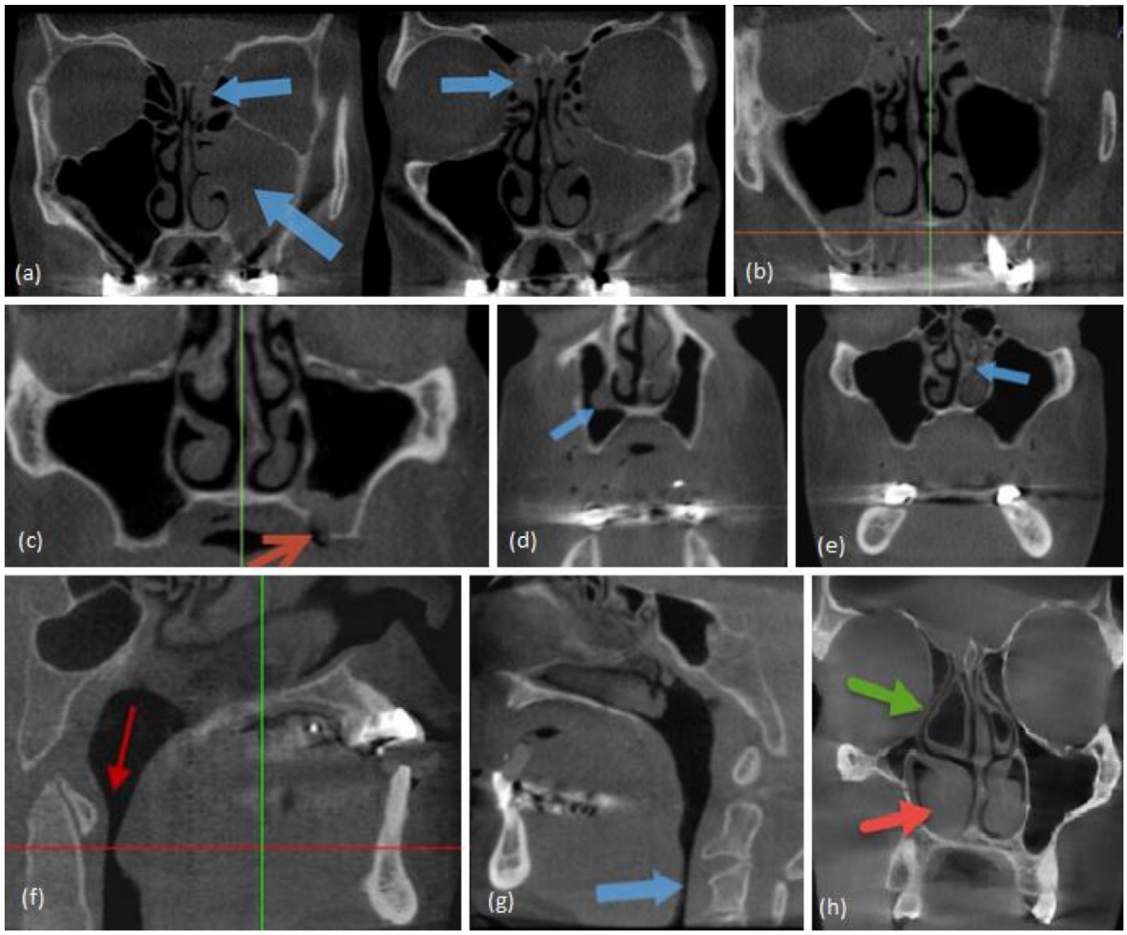

Figure 3 Findings of intermediate significance in the sinuses and airway: (A) sinusitis involving the left maxillary sinus, ethmoid air cells, and possibly front sinuses; (B) mucosal thickening and antral polyposis in the maxillary and ethmoid sinuses; (C) mucosal thickening of left sinus with possible antro-oral fistula; (D) mucous retention pseudocyst in the right maxillary sinus; (E) nasoseptum deviation to the left and narrowing of the ostiomeatal complex; (F) narrowed airway; (G) narrowed airway in the oral pharynx; and (H) large concha bullosa (green) and inferior concha (red).

the virtual plan for implant prosthodontic treatment.[24] CBCT scans allow identification of bony anatomy for ideal implant placement in relation to the prosthetic design prior to surgery.[15] It is important to systemically read the CBCT volume in full,[21,25–28] and to document and inform patients of the findings. Referral to the patient's physician or medical specialist is made when further imaging may be required or to rule out pathology.[25,29] Patients were informed about the findings and referred to a physician or specialist for further imaging, investigation, or medical intervention. All findings were documented in the patients' clinical records.

When reading CBCT volumes, untrained observers might miss important pathology or misidentify normal variants and minor anomalies, causing unwarranted distress for patients and additional costly tests.[22] Knowledge of the anatomy is critical, and referral of the CBCT volume to a radiologist is needed. Radiologists receive formal training on the recognition, handling, incidence, location, and presentation of incidental findings.[22]

Of the one thousand two patients, 921 patients (91.9%) had at least one finding. In a sample of 300 CBCT scans, Price et al found 272 (90.7%) were positive for findings.[23] Warhekar et al had positive findings in 738 (92.8%) out of the 795 total cases that were studied.[30] Barghan et al found a total of 653 incidental findings in 309 of the 400 (77.3%) CBCT scans.[31] Cağlayan and Tozoğlu found an overall rate of incidental findings at 92.8% of a 207 CBCT imaging sample.[32]

Eighty-one patients out of one thousand two (8.1%) did not show any findings, compared to twenty-eight of three hundred (9.3%) scans showed no incidental findings in Price et al.[23]

Sinusitis and airway

The most common finding in this study was sinusitis (52.39%). Lana et al, Caglayan et al, and Price et al found sinusitis at 62.6%, 21.3% and 14.2%, respectively.[23,32,33] Mucosal thickening, mucous retention cysts/pseudocysts are of low significance compared to complete opacification of the sinus, blockage of drainage, and mucoceles. Patients can be either symptomatic or asymptomatic.[22] Inflammatory tissue can progress to invade the paranasal sinuses of ethmoid and frontal sinuses leading to serious consequences if ignored.[22]

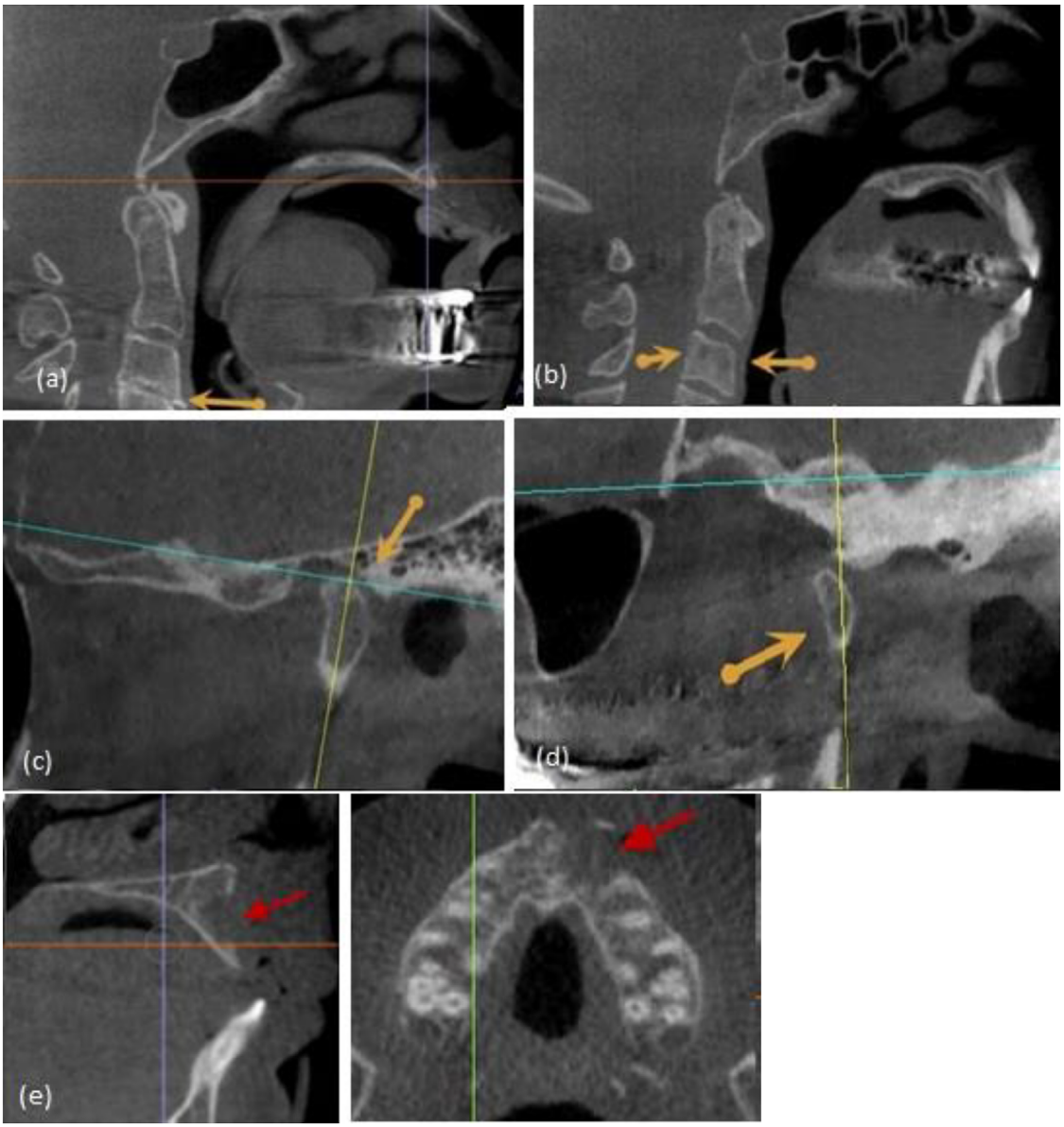

Figure 4 Findings of intermediate significance: (A) degenrative changes of the cervical spine, (B) osteolytic areas in C3, (C) mouth position shows the condyle located posteriorly, (D) open mouth position shows subluxation of the condyle, and (E) fracture in the anterior maxilla.

Deviation of the nasal septum was seen in 100 patients (9.98%) Caglayan et al, Price et al, and Pette et al all found airway issues to represent the most frequent incidental findings at 51.8%, 35%, and 25.5%, respectively.[23,32,34] Caglayan et al and Pette et al found deviation of the nasal septum at (12.6%) and (9.4%), respectively.[32,34] Discontinuity of the airway, or an antra-oral fistula was seen in six patients (0.6%) compared to 17.4% Lana et al.[33] Tonsilloliths was seen in 56 patients (5.59%) compared to Price et al and Pette et al, 4.9% and 10.1%, respectively.[23,34] Tonsillar hypertrophy was seen in 19 patients (1.89%) compared to Allareddy et al (10.7%) Edwards et al (7.48%).[35,36]

Concha bullosa was seen in 16 patients (1.59%) compared to Caglayan et al and Dogramaci et al who noted it at (3.9%) and (1.4%), respectively.[32,37] Retention cysts was seen in 43 patients (4.29%) compared to Price et al, Caglayan et al at, and Pette et al, where it was seen at (5.8%), (2.9%), and (16.4%), respectively.[23,32,34]

Obstructive sleep apnea (OSA)

Narrowing of the airway increases the risk of obstructive sleep apnea (OSA) and was seen in 190 patients (18.96%). It has been reported in the literature at 6.9% and 7.86%.[34,31]

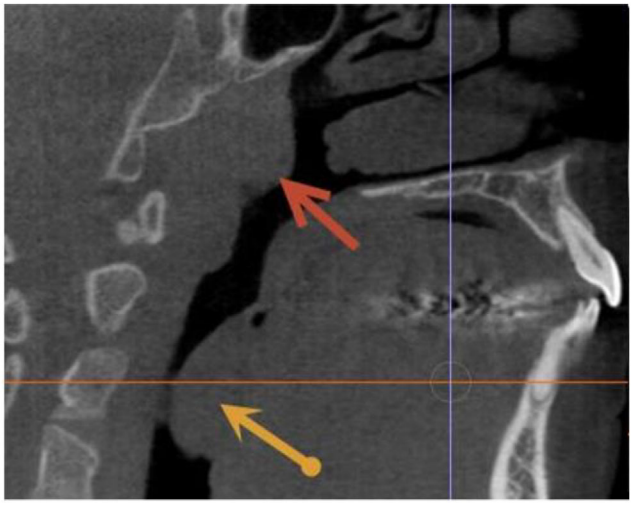

Figure 5 Findings of low significance: enlarged palatal tonsil (yellow), adenoidal hyperplasia (red).

Constriction in airway detected in CBCT scans should be followed up with a referral to a physician or a sleep medicine specialist for proper follow up, which can include interviewing and polysomnography. OSA can present with co-morbidities such as hypertension, obesity, depression, GERD, diabetes, hypercholesterolemia, and asthma.[40]

Dentists have a unique ability to screen patients for untreated OSA by noting a small upper airway clinically[41] or incidentally on CBCT or lateral cephalometric films.[42] Referral to a sleep specialist for follow up and diagnosis is indicated.[41] The dentist can then fabricate an oral appliance in coordination with the specialist.[41]

Degenerative joint disease and TMJ findings

Flattening, sclerosis, and sometimes osteophyte formation, was seen radiographically in 400 patients (39.92%). It has been reported in the literature between 6.17%[38] and 32.6%[39] The presence of degenerative joint disease increases the probability of displaced discs, reduces the size of the condyles, and may predispose the TMJs to dysfunction. Hyperplasia of the joint was seen in two patients (0.20%) compared to (1.7%) in Allareddy et al.[35]

Previous condylar fracture was seen in two patients (0.2%), subluxation of the left condyle was seen in one patient (0.1%), and mandibular and maxillary fractures were each seen once (0.2%). Allareddy observed one case of an unhealed fracture (0.1%).[35]

Cervical spine

Degenerative changes in the cervical spine were seen in 15.01% of these patients evaluated, compared to 16.38%,[31] 4.93%[38] and 45.6%[34] in the literature. Herniation of an invertebral disc, vertebral body factures of C6 (severe), C7, and T1, and nonsegmentation of C2-3, were each seen once (0.1%). Allareddy et al. observed nonsegmentation of C2-3 at (0.2%) and fusion of C2-3 cervical vertebrae once (0.1%).[35] Vertebral fusion was the most predominant finding in the cervical region in Edwards et al's sample (0.6%) who examined younger mean ages.[36]

Carotid artery calcifications

Atherosclerosis is an endovascular disease caused by the formation of intralumenal plaques containing cholesterol affecting the endovascular system, most commonly the heart, brain, and lower extremities.[22,43] Hypertension is one of the most important factors in atheroma formation and in strokes.[44] According to MacDonald et al, these plaques can lead to stenosis or formation of an emboli that can later occlude a cerebral artery.[44] Stroke is a significant cause of death and a leading cause of disability in the United States.[45]

Atherosclerotic calcifications of the carotid arteries were seen in the cavernous portions, base of the skull, and lateral neck in 176 patients (17.56%). In the literature, intracranial calcifications of the carotid arteries range from 17.93%[34] to 60.1%f [47] and extracranial calcifications of the carotid arteries range from 5.66%[34] to 42.88%[48] Carotid calcification does not necessarily indicate stenosis,[46] but this finding can early identify patients at risk.[47] Damaskos et al found a significant correlation between intra- and extracranial calcifications of the ICA.[47,48] Referral to a physician or specialist for further imaging, such as Doppler ultrasound[46] or magnetic resonance imaging (MRI),[49] is indicated for proper diagnosis. There were several patients who were informed of their carotid artery calcifications and referred to their physicians. In their follow up CBCT scans, vascular clips consistent with previous surgery were seen. Other calcifications:

Calcified thyroid and/or triticeous cartilages was seen in three patients (0.3%). Price et al noted calcified thyroid and/or triticeous cartilages in 34 patients out of 300.[23] Stylohyoid ligament calcification was seen bilaterally in one patient (0.1%) compared to Price et al and Pette et al at (9%) and (3.1%), respectively.[23,34] The patient was referred to ENT for further evaluation to rule out Eagle syndrome. Pineal gland calcification was seen in 7 patients (0.7%) compared to Allareddy et al 14.7% and Pette et al 19.2%.[34,35]

Findings in the jaws

Periapical pathology (apical periodontitis, condensing osteitis, root resorption, hypercementosis) was seen in 35 patients (3.49%) compared to (4.3%) and (35.3%) observed by Cağlayan et al and Allareddy et al, respectively.[32,35] Osteoporosis or enlarged marrow spaces were observed in two patients (0.2%) compared to Pette et al who observed it at (2.83%).[34] Cemento-osseous lesion was found in 4 patients (0.40%) compared to 1.8% observed by Allareddy et al.[35] Enostosis/osteosclerosis was seen in 9 patients (0.9%) compared to (14.1%), (6.7%), (1.9%) observed by Allareddy et al, Price et al, and Edwards et al, respectively.[23,35,36]

Benign lesions

Cysts/benign tumors in the jaws were seen in 6 patients (0.6%) and soft tissue mass/tumor was seen in three patients in the jaws (0.3%) compared to Allareddy et al and Pette et al who found soft tissue mass/tumor of the jaws at 3.0% and 6.6%, respectively.[34,35] Soft tissue mass/tumor was seen in two patients in the nasal fossa/maxillary sinus (0.2%), and in two patients in the neck (0.2%). Pette et al observed soft tissue mass/tumor at (0.31%) in the nasal fossa/maxillary sinus and (0.31%) in the pharyngeal airway.[34] Cholesteatoma was seen in four patients (0.4%), compared to Drage et al who observed it at (1.5%).[38]

Benign odontogenic tumors or lesions, such as Keratocystic odontogenic tumors (KCOT), ameloblastomas, central giant cell granulomas, and others have been reported in the literature.[22] CBCT can be useful in depicting the location and extent of the lesions, the effect on bone and adjacent tooth structures, and in developing a radiologic differential diagnosis.[22]

In one of the radiographic findings (refer to Fig 1.e) an odonotogenic cyst or tumor with external root resorption and buccal expansion was identified and suspected. Biopsy showed granulation tissue with abscess and bacterial colonies consistent with morphology of actinomyces.

Malignant lesions

Malignant tumors were seen in three patients (0.3%). Multiple myeloma and rheumatoid arthritis were each seen once (0.1%). Leukemia was suspected radiographically in one patient (0.1%) and in ten cases, calcifications and proliferations required follow up and clinical correlation (1%). Osteomyelitis/osteonecrosis (0.5%) was seen in 5 patients.

In comparison to the literature, Allareddy et al found incidentally three malignancies in a sample size of 1000 subjects (0.3%).[35] Osteomyelitis was seen in 0.4% and 2.83% of sample, by Allareddy et al and Pette et al, respectively.[34,35]

The incidence of a malignant lesion in the jaws and adjacent anatomic structures is low as seen in the literature.[22] However, failure to recognize such lesion can lead to serious consequences, threatening a patient's life.[22] The malignancy can have characteristic features of cortication, density, and definition.[22] It can be expanding, displacing structures causing asymmetry.[22] It can also have effects on the periodontal ligament, mimicking periodontal disease.[22] It can be erosive, such as to the sinus walls.[22]

CBCT can differentiate osseous structures. Distinct soft tissue cannot be differentiated, and soft tissue pathology cannot be accurately illustrated in CBCT images because of the inherent low soft tissue contrast, requiring additional follow-up with the appropriate imaging modalities.[22] When a lesion is suspected, a referral to the patient's physician for a medical CT or an MRI for proper evaluation is needed.

Regarding the pituitary gland calcification finding in Table 3, the patient was referred to have further medical evaluation of the calcification. The pituitary gland calcification turned out to be a benign tumor (craniopharyngioma) in the sella turcica region.

Artificial intelligence (AI)

AI will soon have an impact on the interpretation of medical imaging. There has been collaboration between Google and Deepmind, and other medical centers in the UK and U.S.[50] This provided AI access to learn on a large set of anonymized mammograms from over 96,000 women in the UK and U.S. used for screening of breast cancer.[50] The authors of that study used real-world diagnoses and biopsy-confirmed outcomes to evaluate the predictions of the AI.[50] AI showed an increase in the ability to correctly predict breast cancer compared to human experts, and a reduction of false positive and false negative readings.[50] The study also found that AI is able to detect early signs of cancer before they have progressed to more advanced stages with lower prognoses for treatment.[50] The study suggested that AI can be incorporated to support radiologists, and could benefit areas with a shortage of radiologists to provide access and high quality care.[50] Google is currently working on developing algorithms to aid pathologists in detecting metastatic breast cancer from pathology slides. The large volume of pathology slides requires skilled clinicians, and the microscopic examination can be cumbersome and susceptible to error.[51,52] AI can be used in the future to detect other types of cancers,[51] and could very possibly play a role in dental CBCT in the future.

Conclusion

CBCT scans yield incidental findings of clinical importance for patient care. Proper reading of images and proper diagnosis are crucial for patient safety. The dental clinician performing these scans is therefore obligated to scrutinize the images or refer these scans to an oral and maxillofacial radiologist for proper diagnosis. It is necessary to record incidental findings in patients' clinical records and inform patients of the findings. It is a good practice to update the patients' physician that a CBCT volume is available. The physician can use it for future comparison or might require a radiographic examination that would have been previously described by the dental clinician.

Acknowledgments

The authors of this manuscript would like to thank the staff at Pi Dental Center for their very kind and gentle treatment of the patients and Chris Raines for assistance with data collection.

References

1. Aksoy U, Orhan K. Risk factor in endodontic treatment: topographic evaluation of mandibular posterior teeth and lingual cortical plate using cone beam computed tomography (CT). Medical Science Monitor 2018;24:7508-7516
2. Abdelkarim A. Cone-beam computed tomography in orthodontics. Dent J (Basel) 2019;7:89
3. Van Steenberghe D, Naert I, Andersson M, et al. A custom template and definitive prosthesis allowing immediate implant loading in the maxilla: a clinical report. Int J Oral Maxillofac Implants 2002;17:663-670
4. Vidya KC, Pathi J, Rout S, et al. Inferior alveolar nerve canal position in relation to mandibular molars: a cone-beam

computed tomography study. Natl J Maxillofac Surg 2019;10:168-174
5. Kim TS, Caruso JM, Christensen H, et al. A comparison of cone-beam computed tomography and direct measurement in the examination of the mandibular canal and adjacent structures. J Endod 2010;1191-1194
6. Jacobs R. Preoperative radiologic planning of implant surgery in compromised patients. Periodontol 2000. 2003;33:12-25
7. Rubio-Palau J, Prieto-Gundin A, Cazalla AA, et al. Three-dimensional planning in craniomaxillofacial surgery. Ann Maxillofac Surg 2016;6:281-286
8. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc 2006;72:75-80
9. Vercruyssen M, Cox C, Naert I, et al. Accuracy and patient-centered outcome variables in guided implant surgery: a RCT comparing immediate with delayed loading. Clin Oral Implants Res 2016;;27:427-432
10. Fokas G, Vaughn VM, Scarfe WC, et al. Accuracy of linear measurements on CBCT images related to presurgical implant treatment planning: a systematic review. Clin Oral Implants Res 2018;393-415
11. Bornstein MM, Scarfe WC, Vaughn VM, et al. Cone beam computed tomography in implant dentistry: a systematic review focusing on guidelines, indications, and radiation dose risks. Int J Oral Maxillofac Implants 2014;55-77
12. Roberts JA, Drage NA, Davies J, et al. Effective dose from cone beam CT examinations in dentistry. Br J Radiol 2009;82: 35-40
13. McCollough CH, Bushberg JT, Fletcher JG, et al. Answers to common questions about the use and safety of CT scans. Mayo Clin Proc 2015;90:1380-1392
14. Watanabe F, Hata Y, Mataga I, et al. Retrieval and replacement of a malpositioned dental implant: a clinical report. J Prosthet Dent 2002;88:255-258
15. Balshi SF, Wolfinger GJ, Balshi TJ. Surgical planning and prosthesis construction using computed tomography, CAD/CAM technology, and the Internet for immediate loading of dental implants. J Esthet Restor Dent 2006;18:312-323
16. Daas M, Assaf A, Dada K, et al. Computer-guided implant surgery in fresh extraction sockets and immediate loading of a full arch restoration: a 2-year follow-up study of 14 consecutively treated patients. Int J Dent 2015:824127
17. Lam EW, Ruprecht A, Yang J. Comparison of two-dimensional orthoradially reformatted computed tomography and panoramic radiography for dental implant treatment planning. J Prosthet Dent 1995;74:42-46
18. Kassebaum DK, Nummikoski PV, Triplett RG, et al. Cross-sectional radiography for implant site assessment. Oral Surg Oral Med Oral Pathol. 1990 Nov;70:674-678
19. Orentlicher G, Goldsmith D, Abboud M. Computer-guided planning and placement of dental implants. Atlas Oral Maxillofac Surg Clin North Am 2012;20:53-79
20. Greenstein G, Cavallaro J, Tarnow D. Practical application of anatomy for the dental implant surgeon. J Periodontol 2008;79:1833-1846
21. Tyndall DA, Price JB, Tetradis S, et al; American Academy of Oral and Maxillofacial Radiology. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;817-826
22. Yang J et al: Incidental findings on CBCT. In Scarfe W, Angelopoulos C (eds): Maxillofacial Cone Beam Computed Tomography: Principles, Techniques and Clinical Applications. Springer, 2018; pp 553-584
23. Price JB, Thaw KL, Tyndall DA, et al. Incidental findings from cone beam computed tomography of the maxillofacial region: a descriptive retrospective study. Clin. Oral Impl. 2012;1261-1268
24. Sherry JS, Balshi TJ, Sims LO, et al. Treatment of a severely atrophic maxilla using an immediately loaded, implant-supported fixed prosthesis without the use of bone grafts: a clinical report. J Prosthet Dent 2010;103:133-138
25. Miracle AC, Mukherji SK. Conebeam CT of the head and neck, Part 2: clinical applications. Am J Neuroradiol 2009;30:1285
26. Edwards R, Altalibi M, Flores-Mir C. The frequency and nature of incidental findings in cone-beam computed tomographic scans of the head and neck region: a systematic review. J Am Dent Assoc 2013;144:161-170
27. Theodoridis C, Vaitsidis Z, Angelopoulos C. Incidental findings on CBCT and classification according to their significance. Oral Surg, Oral Med, Oral Pathol Oral Radiol [Internet] 2019;127:47
28. Dief S, Veitz-Keenan A, Amintavakoli N, et al. A systematic review on incidental findings in cone beam computed tomography (CBCT) scans. Dentomaxillofac Radiol 2019;48:20180396
29. Monsarrat P, Galibourg A, Nasr K, et al. Incidental findings in dental radiology are concerning for family doctors. Open Med (Wars) 2019;14:467-478
30. Warhekar S, Nagarajappa S, Dasar PL, et al. Incidental findings on cone beam computed tomography and reasons for referral by dental practitioners in Indore city (M.P.). J Clin Diagn Res 2015;ZC21-ZC24
31. Barghan S, Tahmasbi Arashlow M, Nair MK. Incidental findings on cone beam computed tomography studies outside of the maxillofacial skeleton. Int J Dent 2016:9196503
32. Cağlayan F, Tozoğlu U. Incidental findings in the maxillofacial region detected by cone beam CT. Diagn Interv Radiol 2012;159-163
33. Lana JP, Carneiro PM, Machado Vde C, et al. Anatomic variations and lesions of the maxillary sinus detected in cone beam computed tomography for dental implants. Clin Oral Implants Res 2012;1398-1403
34. Pette GA, Norkin FJ, Ganeles J, et al. Incidental findings from a retrospective study of 318 cone beam computed tomography consultation reports. Int J Oral Maxillofac Implants 2012;595-603
35. Allareddy V, Vincent SD, Hellstein JW, et al. Incidental findings on cone beam computed tomography images. Int J Dent 2012:871532
36. Edwards R, Alsufyani N, Heo G, et al. The frequency and nature of incidental findings in large-field cone beam computed tomography scans of an orthodontic sample. Prog Orthod 2014;37
37. Doğramacı EJ, Rossi-Fedele G, McDonald F. Clinical importance of incidental findings reported on small-volume dental cone beam computed tomography scans focused on impacted maxillary canine teeth. Oral Surg Oral Med Oral Pathol Oral Radiol 2014;e205-e209
38. Drage N, Rogers S, Greenall C, et al. Incidental findings on cone beam computed tomography in orthodontic patients. J Orthod 2013;40:29-37
39. Balshi T, Wolfinger G, Yang J, et al. Prevalence of non-dental pathology in cone beam computed tomography studies for dental implants. J Implant Adv Clin Dent 2013;3:21-26

40. Pinto JA, Ribeiro DK, Cavallini AF, et al. Comorbidities associated with obstructive sleep apnea: a retrospective study. Int Arch Otorhinolaryngol 2016;20:145-150
41. Quan SF, Schmidt-Nowara W. The role of dentists in the diagnosis and treatment of obstructive sleep apnea: consensus and controversy. J Clin Sleep Med 2017;13:1117-1119
42. Solow B, Skov S, Ovesen J, et al. Airway dimensions and head posture in obstructive sleep apnoea. Eur J Orthod 1996;18:571-579
43. Tegos TJ, Kalodiki E, Sabetai MM, et al. The genesis of atherosclerosis and risk factors: a review. Angiology 2001;52:89-98
44. MacDonald D, Chan A, Harris A, et al. Diagnosis and management of calcified carotid artery atheroma: dental perspectives. Oral Surg Oral Med Oral Pathol Oral Radiol 2012;114:533-547
45. Gorelick PB, Sacco RL, Smith DB, et al. Prevention of a first stroke: a review of guidelines and a multidisciplinary consensus statement from the National Stroke Association. JAMA 1999;281:1112-1120
46. Almog DM, Horev T, Illig KA, et al. Correlating carotid artery stenosis detected by panoramic radiography with clinically relevant carotid artery stenosis determined by duplex ultrasound. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;94:768-773
47. Damaskos S, Tsiklakis K, Syriopoulos K, et al. Extra- and intra-cranial arterial calcifications in adults depicted as incidental findings on cone beam CT images. Acta Odontol Scand 2015;73:202-209
48. Damaskos S, Aartman IH, Tsiklakis K, et al. Association between extra- and intracranial calcifications of the internal carotid artery: a CBCT imaging study. Dentomaxillofac Radiol 2015;44:20140432
49. Lee J, Kil J, Kim DW, et al. Usefulness of Plaque Magnetic Resonance Imaging in Identifying High-Risk Carotid Plaques Irrespective of the Degree of Stenosis. J Cerebrovasc Endovasc Neurosurg 2017;19:291-300
50. McKinney SM, Sieniek M, Godbole V, et al. International evaluation of an AI system for breast cancer screening. Nature 2020;577:89-94
51. Steiner DF, MacDonald R, Liu Y, et al. Impact of deep learning assistance on the histopathologic review of lymph nodes for metastatic breast cancer. Am J Surg Pathol 2018;42:1636-1646
52. Liu Y, Gadepalli K, Norouzi M, et al. Detecting cancer metastases on gigapixel pathology images. arXiv:1703024422017 [Preprint]. 2017 [cited 2021 Jan 14]: [13 p.]. Available from: https://arxiv.org/abs/1703.02442 (2017)