Interpreting the CBCT Data Volume in Orthodontic Cases: “You Should See What You May Be Missing”!

(This article was published in a 2-part series by OrthoTown as a supplement in 2011)

Dale A. Miles  BA, DDS, MS, FRCD(C)
Diplomate, ABOM; Diplomate, ABOMR

This is a 2-part article designed to help clinicians understand the more common findings they will encounter in the anatomic regions they capture in larger FOV (Field-of-View) CBCT machines. Many of these findings will also be seen in smaller FOV machines when the volume capture is moved around to view things like the temporomandibular joint or third molar regions. So this article will be of interest to all clinicians, not just orthodontists. Part I will address the skull, oropharynx, cervical soft tissues and cervical spine. Part II will cover the paranasal sinus regions, nasal cavity, sella tursica region and TMJ. Anyone who owns or uses the data from a CBCT machine will see these pathologic findings and need to recognize them. Some findings are incidental but reportable/recordable. May cited in this article can significantly impact the patient’s health and after finding them, the patient MUST be referred to a medical specialist for further evaluation and management. Some might even save your patient’s life. Missing the most important findings could lead to harm to the patient and result in litigation. All of this information will benefit both you and your patients.

Part I

Introduction

It should be intuitively apparent to the orthodontist that there are important structures to examine beyond the dentoskeletal bases in any cone beam data volume that require interpretation. Typical anatomic structures that need to be examined in each volume include the:

1. skull and its contents
2. oropharyngeal tissues
3. cervical soft tissues
4. cervical spine
5. paranasal sinuses
6. nasal cavity
7. sella tursica and parasellar regions
8. temporomandibular joint complexes
This article will instruct the orthodontist on the methodology of examining these important anatomic regions and illustrate some of the more frequent findings in each of these areas. Some of the findings may simply be noteworthy are reported to and some will inevitably lead to referral either to another dental specialist or a medical provider. All of the figures seen in this article come from the author’s radiology practice; that is, CBCT volumes referred by dentists and dental specialists using CBCT.

**The Skull and Its Contents**

Most commonly there are physiologic calcifications seen within the skull on large field of view (FOV) CBCT machines. These include the more common calcifications of the **pineal gland**, **choroid plexuses** and **falx cerebri**. Although calcification of the falx cerebri is seen in the nevoid basal cell carcinoma syndrome (Gorlin-Goltz) it is, nevertheless, a common finding, about 10 % of the general population, unassociated with a syndrome. Figure 1 is an example of such a normal falx finding.

Pineal gland calcification is usually physiologic in nature, occurring in about 40% of the general population by age 20 years. Pineal calcifications <1cm in diameter are considered to be normal. Calcifications > 1 cm could indicate a lesion such the pineal gland. Figure 2 shows normal, physiologic calcification of the pineal gland.

![Figure 1. Calcification of the falx in an axial view. Center. In a sagittal view. Right. In a coronal view. All slices are at 0.1 mm thickness.](image)
Figure 2a. White arrow points to a calcification of the pineal gland in a MIP (Maximum Intensity Profile) image, imaged at about 15mm thickness. This MIP processing tool is excellent for looking at soft tissue calcifications. Blue arrows point to choroid plexus calcifications bilaterally. Figure 2b. A thin slice (0.1mm) axial view of a pineal gland calcification.

Calcification of the choroid plexuses is usually bilateral and is only worrisome if it "exuberant" calcification is seen in young children1. Figure 2 left and Figure 3 below show physiologic choroid plexus calcifications.

Figure 3a. Arrows point to bilateral calcification of the choroid plexuses in a coronal section. Figure 3b. A MIP image showing large, diffuse choroid plexus calcifications and another calcification of pineal gland (white arrow).
Oropharyngeal Tissues

Tonsilloliths are common finding either unilaterally or bilaterally in the pharyngeal tissues. These calcifications can occur singly or in clusters. Although all are noteworthy, multiple calcifications can be a source of malodor for the patient\(^3\), often undiagnosed in the dental office. They can cause repeated inflammatory problems and even ulcerate to the surface of the tonsillar crypt tissues\(^3\). Figure 4 illustrates more florid examples of tonsilloliths.

![Figure 4a. Arrows point to bilateral groupings of tonsilloliths. This is a coronal MIP image reconstructed at about 20 mm. Figure 4b. A thin slice coronal image showing large, diffuse aggregation of tonsilloliths in the left pharyngeal tissues.](image)

Although not specifically in the oropharyngeal airway space, the components of the stylohyoid ligament chain are found adjacent to this region and calcification of some or all of their parts can lead to symptoms\(^4-6\). Calcified elongated stylohyoid ligaments are quite common in any age group. It is only when symptoms arise that treatment is indicated. Figures 5 and 6 illustrate unilateral and bilateral cases. Eagle's syndrome has two presentations: the classic or more common is the feeling of a sharp pain like a fishbone in the throat upon swallowing (dysesthesia), the second presentation is one of a dull pain in the throat with radiating pain to the parietal, supra-orbital or infra-orbital regions\(^7\).
Figure 5a. Unilateral calcification and elongation of right stylohyoid ligament, panoramic reconstruction at 25mm.

Figure 5b. 3D color reconstructed image of same elongated stylohyoid ligament as in Figure 5a.

Figure 5c. 3D color reconstruction in coronal section at 30 mm to show more detail of stylohyoid calcification.
Cervical Soft Tissues

In the cervical region in CBCT examinations the most important pathologic finding to recognize our calcifications in the carotid arteries either unilateral or bilateral. Sclerotic plaques associated with hypertension and increase stroke potential have been seen on panoramic images and reported for many years. Although some are bilateral most are seen on one side of the image only. Many are probably
missed on conventional panoramic because of the positioning of the focal trough in some machines; however, none should be missed on CBCT images. Bilateral, circumferential calcifications of the carotid arteries in the neck region sometimes in conjunction with concomitant parasellar calcifications of the internal carotid will be found within CBCT volumes. A subgroup of the larger numbers of carotid plaques these bilateral circumferential findings may indicate MAC (Medial Arterial Calcification) seen an undiagnosed or uncontrolled type II diabetes mellitus possibly in patients with end stage renal disease (ESRD)\textsuperscript{11-13}. Figures 7-9 below illustrate cases with calcifications of the carotid arteries, routinely found in CBCT data volumes.
Figure 7a. Large calcification of the left carotid artery at the level of C3/C4. Figure 7b. 3-D color reconstruction of the same calcification seen in 7a. Figure 7c. 3-D color reconstruction using the "Cube" image processing tool and OnDemand 3D (CyberMed International, Seoul, Korea and Irvine, California) viewed from the coronal (left side) caudal (right side) positions. Figure 7d. Bilateral circumferential calcifications of the internal carotid artery in the parasellar region seen in a thin slice (1.0 mm) coronal section and a thick slice (5.0 mm) MIP image.

Figure 8a. Bilateral circumferential calcifications of the left and right carotid arteries. Figure 8b. MIP reconstruction demonstrating the same calcifications at the level of C3C4.
Figure 8c. 3D full color reconstruction of the patient's skull demonstrating bilateral carotid calcifications. The left appears quite circumferential.

Figure 8d. Panoramic MIP image reconstructed at about 35 mm showing bilateral calcifications but no indication that they are circumferential as in figures 8a and 8c above.
Figure 9a. Reconstructed Panoramic MIP image (35 mm) demonstrating the large calcification on the patient’s left side. There is no indication of any involvement of the right carotid artery even at this focal trough thickness. Figures 9b and 9c. Axial and coronal images showing calcifications of each side. Figures 9d and 9e. 3-D color reconstructed views of the left and right side. Figures 9f. Circumferential calcifications around curves segments of internal carotid in the parasellar regions bilaterally. Figure 9g. Calcifications along the length of the internal carotid artery bilaterally has occurs from inferiorly to superiorly.
Figure 10. Drawing of parasellar region showing relationship of internal carotid artery to pituitary fossa (sella tursica). Compare this drawing with figures 9F and 9g above and Figure 17 below.

Cervical Spine

Of course the most common changes found in the cervical spine are those that we also see in the TM joint complex. These include subchondral sclerosis, subchondral cyst formation, loss of joint space and osteophyte formation. Occasionally we also see a “loose body”, especially at the atlantoaxial junction and less commonly calcification of the paraspinal ligaments especially the anterior. What is probably not appreciated by the orthodontist or dentist are that most of these changes are also seen in the facet joints, and not just the vertebral bodies. The examples in figures 11 to 13 below show most of these changes. In over 9000 CBCT cases that I have reviewed to date there also been several lesions of the vertebral bodies, including possible metastatic lesions.
Figures 11a,b. Loss of joint space osteophyte and subchondral cyst formation are seen in the vertebral bodies C5 and C6. Figure 11c. Remodeling and loss of joint space seen in the right facet joint between C3 and C4 and the same case. Figures 1d-f. Similar changes in another case in the vertebral body C3 to C7. The osteophyte formation loss of joint space are consistent with osteoarthritis. The subchondral cyst formation seen in the vertebral bodies C4 and C5 are then most likely consistent with osteoarthritic changes. However, multiple site involvement of these radiolucent areas could also be consistent with metastases.
Figures 12 a-b. Gross remodeling subchondral sclerosis and subchondral cyst formation seen in the left facet joint between C3 and C4. Figures 12c-d. Loss of joint space, subchondral cyst formation, osteophyte formation and a loose body at the atlantoaxial junction are seen in this case. In addition there is a reverse curvature at the level of vertebral body C3 and C4 consistent with a cervical lordosis. In this case both the vertebral bodies in facet joints show comparable changes. All are consistent with osteoarthritis.
Figure 13a. An unusual change in the left facet joint between C3 and C4. The enlargement and mixed appearance of the lesion suggest a bony tumor rather than osteoarthritic change. Figure 13b. A thin slice sagittal view through a portion of the lesion almost suggests some multilocularity. Figure 13c. The radiolucency seen in the superior aspect of C4 is suggestive of a simple subchondral cyst. However, the changes seen in figure 1d. In the facet joint are not consistent with osteoarthritic change. Figure 13e. A 3-D color reconstruction shows a gross remodeling of this left facet joint. The diagnosis of this particular lesion is not known at this time.

All images were created using OnDemand3D software from CyberMed (310 Goddard Way, Suite 250, Irvine, CA 92618, USA and Seoul, Korea)
Interpreting the CBCT Data Volume in Orthodontic Cases: “You Should See What You May Be Missing”! Part II

Dale A. Miles BA, DDS, MS, FRCD(C)
Diplomate, ABOM; Diplomate, ABOMR

This is a 2-part article designed to help clinicians understand the more common findings they will encounter in the anatomic regions they capture in larger FOV (Field-of-View) CBCT machines. Many of these findings will also be seen in smaller FOV machines when the volume capture is moved around to view things like the temporomandibular joint or third molar regions. So this article will be of interest to all clinicians, not just orthodontists. Part I will address the skull, oropharynx, cervical soft tissues and cervical spine. Part II will cover the paranasal sinus regions, nasal cavity, sella turcica region and TMJ. Anyone who owns or uses the data from a CBCT machine will see these pathologic findings and need to recognize them. Some findings are incidental but reportable/recordable. May cited in this article can significantly impact the patient’s health and after finding them, the patient MUST be referred to a medical specialist for further evaluation and management. Some might even save your patient’s life. Missing the most important findings could lead to harm to the patient and result in litigation. All of this information will benefit both you and your patients.

Part II

Paranasal Sinuses

The paranasal sinuses include the maxillary, sphenoid and frontal sinuses. Although not strictly sinus spaces, the ethmoid air cells are also included in this category. All of these spaces communicate one with the other. Inflammaotry changes are seen in all these spaces; however, the maxillary sinuses and ethmoid air cells seem to be involved more commonly. Frontal and sphenoid involvement is less common. Nevertheless if changes are seen in the sphenoid sinus region, because of the important neural, vascular and optic structures which travel in the parasellar region, referral to an otolaryngologist and/or the patient’s primary care provider is mandatory. Inflammatory or infectious changes in the sphenoid sinus could disseminate rather rapidly because of the proximity of the neurovascular structures in this region. In addition diffuse headache symptoms are common with paranasal sinus problems and can be confusing to delineate and diagnose. Most of the changes seen in the paranasal sinus region are from chronic inflammatory complaints. But, things like antroliths, foreign bodies and even osteoma can to occur in any of these spaces. Furthermore, dental problem such as apical periodontitis and chronic periodontal conditions can affect the maxillary sinus and caused mucosal
alterations. If the FOV (field of view) fails to include all of the paranasal sinus regions and substantial changes are seen in the more inferior spaces such as the maxillary sinus and ethmoids, then it may be necessary to reimage the patient or referred them to an ENT specialist for clinical and endoscopic evaluation. The figures below demonstrates some of these problems.
Figure 14a-b. Blue arrows in the left image (axial view) and the white arrow in the right image (sagittal view) show a thickened lateral wall and a thickened posterior wall of the right maxillary sinus. The term for this is called "hyperostosis" and is indicative of a chronic inflammatory complaint or disease process. Figure 14c. Hyperostosis is also seen in this coronal view of the right antrum. Figure 14d. The white arrow shows inflammation which is probably blocking the ostium (the communication between the maxillary sinus in the middle meatus). Blockages of this sort often lead to retrograde inflammatory change in the ethmoid air cells, frontal sinus and sphenoid sinus.
Figure 15a. A thin slice coronal view of maxillary antra and ethmoid air cell involvement. Figure 15b. Axial view showing ethmoid air cell opacification seen in figure 15a. Figure 15c-d. Axial and coronal views of the frontal sinus involvement in the same case. Note the more florid involvement of the left frontal sinus.
Figure 16a. Bilateral maxillary sinus involvement (axial view). Figures 16b. Axial view showing ethmoid air cell involvement in uniform thickening in sphenoid sinuses, both left and right. Figure 16c. Ethmoid air cell involvement more superiorly. Figure 16d. Bilateral involvement of the frontal sinuses in an axial view. Figure 16e. Inflammatory changes in the frontal sinus, ethmoid air cell region, and sphenoid sinus. Note how these spaces communicate one with the other. Figure 16f. Sagittal view of sphenoid sinus involvement in the same case. Figures 16g and 16h. Thin slice coronal sections showing bilateral maxillary sinus involvement and involvement of the superior ethmoid air cell complex as well as sphenoid sinuses again bilaterally.
Nasal cavity

Anatomy of the nasal cavity is quite complicated. Besides typical structures like the turbinates and meatal shadows and nasal spine, there are additional anatomic structures like the uncinate process, the ostium, the ethmoid air cells, nasolacrimal ducts, sphenoethmoid recess, and frontal sinus ostium. Luckily, as in the paranasal sinuses, most abnormal things will be radiopaque. Below is an anomaly that occurs commonly in the nasal cavity called "concha bullosa". This is an aeration or pneumatization of the middle turbinate structure. It can be uni- or bilateral. When inflammatory change occurs in the nasal cavity, either originating there or spread from other paranasal sinus spaces, this anomaly can also have inflammatory problems. There are examples of both normally appearing concha bullosa and some with inflammatory change.
Figure 17a. Axial view of bilateral pneumatization anomalies called concha bullosa (blue arrows). Figure 17b. Unilateral concha bullosa anomaly of left middle turbinate in coronal slice (blue arrow). Figures 17c,d. Inflammatory change filling one half of the concha bullosa anomaly in the right middle turbinate; 17c. axial view (blue arrow), 17d. coronal view (blue arrow). 17e. Inflammatory material filling the right middle turbinate completely in an axial view. 17f. The same patient showing this change in a coronal slice. The left middle turbinate is patent. There is some mucosal thickening in the right antrum identified by the lowest blue arrow. Figure 17g. A possible mucocele or pyocele in the superior ethmoid air cell complex. The round nature of the lesion suggest a fluid.

Sella tursica and Parasellar Regions

Adenomas, craniopharyngiomas and disorders such as acromegaly can affect the size of the sella tursica\(^\text{14}\). However, to date, in over 9000 CBCT scans I have seen only one enlarged sella tursica but many parasellar changes as were described in the section on carotid calcifications; namely, calcification of the internal carotid artery. Since the contents of the pituitary fossa (sella tursica) can only be seen by magnetic resonance imaging, the clinician is more likely to see the parasellar changes. Figure 18 below again illustrates the calcification seen in the internal carotid arteries. Since uncontrolled Type II diabetes mellitus (NIDDM - Non Insulin Dependent Diabetes Mellitus), especially when the renal involvement is severe (as in ESRD-end stage renal disease), is so prevalent in the North American population, the clinician is more likely to discover calcified arteries rather than altered size of the sella tursica.
**Figure 18a.** Bilateral calcification of the internal carotid arteries on each side of the sella just posterior to the sphenoid sinus. **Figure 18b.** The same calcifications as they loop anteriorly seen just superior to the sphenoid sinus and below the anterior clinoid processes.

**Temporomandibular Joint Complexes**

Of course the most common changes affecting the condylar head and sometimes the adjacent bone in the glenoid fossa are the same as those that affect the cervical spine another weight-bearing joints. These include:

1. osteophyte formation
2. subchondral cyst formation
3. subchondral sclerosis
4. surface erosion
5. lipping
6. loss of joint space

In addition to these changes of osteoarthritic the clinician may also see hyper or hypoplasia of one condylar head relative to the other, osteochondritis dissecans, avascular necrosis (AVN), loose body formation and occasionally synovial chondromatosis. In conventional 2-D radiographic views such as panoramic or tomographic views loose bodies and even subchondral cyst formation can be misinterpreted. The focal trough layer or tomographic slice may not depict the true situation as can be seen in color 3-D reconstructed views or even multiplanar views of the same joint. Figures 19a-19k below show a number of these temporomandibular joint changes and disorders.
**Figures 19 a-c.** These three images reveal small subchondral cysts in the left and right TMJ condyles. Surrounding these lucent areas are regions of subchondral sclerosis. **Figures 19d-g** reveal remodeling of the right condylar head relative to the left, subchondral cysts and surface erosions. **Figures 19 h and i** show subchondral sclerosis on the left condylar head on the superior surface. **Figures 19j and k** reveal lipping of both condylar heads and loose bodies in the left TMJ space.

**Osteophyte Vs Lipping**

Until clinicians were able to see the changes on the temporomandibular joint condyles in 3-D reconstruction, the terms "bird-beak" and osteophyte were often used as synonyms in 2-D planar imaging such as panoramic, lateral cephalometric and even tomographic slices. So-called "bird-beak" changes were interpreted as such when indeed many cases may have represented lipping on the anterior aspect of the condyle, simply captured in a relatively thin slice, predominantly sagittal view. Figures 20a-c demonstrates this pitfall.
Figure 20a. This thin slice sagittal view of the left condylar head shows a pointed appearance on the anterior aspect resembling a "birds-beak". Figure 20b. This 3-D reconstruction of the left condyle seems to mirror somewhat figure 19a. There appears to be a projection on the anterior surface which could be mistaken for an osteophyte. Figure 20c. This 3-D reconstructed coronal view reveals a deep pterygoid fovea and significant lipping of the anterior surface. There is no birds beak or osteophyte on this condyle, simply unaltered surface morphology, deep depression and growth of the bone anteriorly.

Conclusions:

Relatively common pathologic findings have been reviewed for the anatomic area seen in large FOV CBCT machines. While all of these findings are certainly reportable there are only a few which are truly significant and would impact the systemic health of the patient. Significant findings such as calcification of arteries, airway masses, florid paranasal sinus disease and lucencies in the vertebral column could lead to a catastrophic health event for the patient. Knowledge of these more common findings and normal anatomy of the region cited will help the clinician avoid a missed diagnosis and possibly a subsequent legal problem. Even though the clinician does not have to make a diagnosis based on the radiographic findings alone, he or she must examine the volume or referred for examination to an oral maxillofacial radiologist or other competent provider so that significant findings are not missed. This practice of referral is not only prudent, but also professionally mandated in the American Dental Association's Code of Ethics 17.

All images were created using OnDemand3D software from CyberMed (310 Goddard Way, Suite 250, Irvine, CA 92618, USA and Seoul, Korea)

This article was published in a 2-part series by OrthoTown as a supplement in 2011
References


17. www.ada.org/sections/about/pdfs/ada_code.pdf - 2010-04-30
Author information:

**Dale A. Miles** BA, DDS, MS, FRCD(C)  
Dip. ABOMR, Dip. ABOM  
Professor of Radiology, Arizona School of Dentistry & Oral Health and Adjunct professor, University of Texas San Antonio.

Dr. Miles was a Professor of Oral and Maxillofacial Radiology and Associate Dean for Clinical Affairs at the Arizona School of Dentistry & Oral Health. He also held positions as Chair of the Department of Oral Health Sciences at the University of Kentucky and graduate program director of Diagnostic Sciences at Indiana University. He is a diplomate of the American Board of Oral and Maxillofacial Radiology and the American Board of Oral Medicine. Dr. Miles has been named one of the “TOP 100 CLINICANS IN CE” for the last 8 years by Dentistry Today. He has authored over 130 scientific articles and 5 textbooks, including the latest on Cone Beam Imaging. Dr. Miles has been a Consultant to the US Navy Postgraduate Dental School in Oral Diagnosis, Oral Medicine and Oral Radiology for over 15 years. Dr. Miles has a web site for teaching dentists and auxiliaries about digital imaging at [www.learndigital.net](http://www.learndigital.net). He is in full-time practice of Oral and Maxillofacial Radiology in Fountain Hills, Arizona. To date he’s read over 15,000 cone beam CT scans for dental clients.

**Websites for Dr. Miles**

http://www.learndigital.net

http://www.easyr iter.com  (CBCT report generating software)

http://www.interactiveimagingtv.com  (CBCT videos)