Cone-beam computed tomography is not the imaging technique of choice for comprehensive orthodontic assessment

Demetrios J. Halazonetis
Kifissia, Greece

It was a pleasure to see that Dr Larson did not take the extreme view of proposing cone-beam computed tomography (CBCT) as a routine diagnostic modality—ie, for every patient, irrespective of malocclusion or other patient-specific factors—as some orthodontic postgraduate programs in the United States seem to do. Even so, he does recommend CBCT as the standard procedure, stating in his conclusions that “CBCT has replaced conventional lateral cephalograms and panoramic images as the most commonly ordered imaging for comprehensive orthodontic patients.” In my Counterpoint, I will try to present arguments against CBCT as the imaging technique of choice for comprehensive orthodontic assessment.

Assuming that use for every patient is not advocated, what are the patient selection criteria? The answer should stem from a comprehensive assessment of the benefits and burdens to each patient. This assessment cannot be completely objective, but our decision making should be based on current evidence, which could also serve as the basis to develop general guidelines. Such guidelines already exist. The SEDENTEXCT project of the European Union had as its primary goal “to acquire key information necessary for sound and scientifically based clinical use of CBCT” and “to use this information to develop evidence-based guidelines dealing with justification, optimization and referral criteria for users of dental CBCT.” The guidelines section dealing with orthodontic diagnosis concludes that “large volume CBCT should not be used routinely for orthodontic assessment.”

The British Orthodontic Society guidelines give a similar recommendation: “routine use of CBCT even for most cases of impaction of teeth . . . cannot yet be recommended.”

A similar conclusion was adopted by the American Association of Orthodontists in 2010: “the AAO recognizes that while there may be clinical situations where a cone-beam computed tomography (CBCT) radiograph may be of value, the use of such technology is not routinely required for orthodontic radiography.”

If guidelines already exist, what is the purpose of this debate? First, it is an opportunity to make these guidelines well known to the orthodontic community at a time when CBCT use is increasing. The SEDENTEXCT guidelines are based on a systematic review of the literature, thus representing current evidence-based knowledge at a confidence level much higher than this debate can achieve. Most importantly, however, is that these guidelines are not compulsory. The use of ionizing radiation is governed by law in most countries, but all the law requires is clinical justification. The guidelines are designed to assist the clinician in the justification process. I hope that this debate will convince clinicians to follow the guidelines’ recommendations.

RADIATION BURDEN

The effects of ionizing radiation are considered stochastic events. This signifies that the risk, not the severity, of the condition (eg, cancer) depends on the dose. Using a low-dosage vs a high-dosage CBCT machine will not result in cancers that are easier to treat, only fewer of them. The probability of an important stochastic effect (cancer and severe hereditary effect) is $7.3 \times 10^{-2}$ Sv. For patients aged 10 to 20 years, this doubles to approximately 0.15 Sv. Since a large field-of-view CBCT will provide a dose of 68 to 368 μSv compared with approximately 30 μSv for the cephalometric and panoramic combination, this translates to a risk of about 1 in 170,000 to 1 in 20,000 above the current customary procedure. In the United States, more than 1.6 million orthodontic patients start treatment every year. If each patient had 1 CBCT image, this would result in 10 to 80 additional cancer
cases per year. Is this a risk worth taking? This is not an easy question and depends mainly on the benefit to the patient. What significant improvements in patient outcomes does CBCT offer? To answer, we should not confuse the benefits to the patient with the technical capabilities of CBCT technology. The fact that CBCT images are 3-dimensional is not directly relevant. Justification for CBCT images can only be considered when the treatment outcome will not only be better because of them, but also significantly better to outweigh the above risks.

**EFFICACY**

The following terms are used to evaluate the efficacy of diagnostic imaging procedures: technical efficacy, diagnostic accuracy efficacy, diagnostic thinking efficacy, therapeutic efficacy, patient outcome efficacy, and societal efficacy. These efficacies constitute a hierarchy of levels of increasing importance. The top 2 levels evaluate whether the imaging method produces a net benefit to the patient and society in general, and should dictate our imaging policy. Regarding CBCT and its use in orthodontics, no such studies have been conducted. We will consider the relevant evidence for each of the lower 4 levels, focusing on large field-of-view protocols, since only these can provide reconstructed lateral cephalometric and panoramic views, similar to conventional radiographs.

Technical efficacy is related to the quality of the image. The dimensional accuracy of CBCT images has been well established. Voxel size is typically 0.3 to 0.4 mm, corresponding to a lower resolution than that of conventional intraoral radiographic imaging. Artefacts and noise are higher than those observed in multi-slice computed tomography, making it difficult, if not impossible, to obtain consistent density values and resulting in low contrast and poor depiction of soft tissues. Segmentation is problematic, and even high-contrast objects, such as teeth, are measured with errors that can exceed 1 mm, limiting clinical usefulness.

Diagnosis thinking efficacy evaluates whether the imaging method changes the diagnosis from the pre-test situation. Therapeutic efficacy assesses whether the test produces changes to the treatment plan. These efficacies have been evaluated for impacted third molars and impacted canines. CBCT images are perceived to be more useful than traditional radiographs for such cases and might change the recommended treatment plan in approximately 30% of them. However, no patient outcome efficacy studies have been conducted, and CBCT is recommended only when “the information cannot be obtained adequately by lower dose conventional (traditional) radiography.”

Assuming that use for every patient is not advocated, what are the patient selection criteria? The answer should stem from a comprehensive assessment of the benefits and burdens to each patient.

ENTEXCT guidelines conclude that “CBCT is not indicated as a routine method of imaging periodontal bone support,” although it might be indicated in selected patients, but preferably not with a large field of view. The American Board of Orthodontics includes CBCT images as an option to document periodontal status but does not consider radiographic images, in general, as compulsory data and gives priority to clinical examination and conventional radiography.

Diagnostic thinking efficacy evaluates whether the imaging method changes the diagnosis from the pre-test situation. Therapeutic efficacy assesses whether the test produces changes to the treatment plan. These efficacies have been evaluated for impacted third molars and impacted canines. CBCT images are perceived to be more useful than traditional radiographs for such cases and might change the recommended treatment plan in approximately 30% of them. However, no patient outcome efficacy studies have been conducted, and CBCT is recommended only when “the information cannot be obtained adequately by lower dose conventional (traditional) radiography.”
anchorage rather than improper localization. The authors acknowledged that the initial clinical and radiographic signs were sometimes sufficient to diagnose properly but were misinterpreted by the clinician. There are numerous cases when an impacted maxillary canine can be clearly localized based on conventional radiographs and clinical examination (e.g., palpation, position, and inclination of adjacent teeth), and no further imaging is justified.

Regarding resorption of adjacent teeth, diagnostic thinking efficacy and therapeutic efficacy studies showed that resorption defects can be identified better with CBCT images, but these studies mostly used a medium or small field of view.

Dr Larson also referred to the temporomandibular joint, but asymptomatic patients surely do not need temporomandibular joint imaging. Condylar position in the fossa can certainly be seen on CBCT images, but this information should not affect our diagnosis and treatment plan. The value of temporomandibular joint imaging even for patients with temporomandibular disorders is a debatable subject, and there is no evidence to show that CBCT images will provide better treatment.

It seems, therefore, that CBCT might benefit some patients with the conditions mentioned above, but no evidence exists for the remaining majority of our patients. The application of 3-dimensional cephalometrics, or increased measurement accuracy, could be an indication. However, currently, there are no established 3-dimensional cephalometric analyses and no 3-dimensional normative data. CBCT images are used to simulate old technology—i.e., reconstruct 2-dimensional lateral cephalometric views. In this transitional, backward step, we should not carry with us the misconceptions of the early cephalometric era: strict adherence to cephalometric standards and blind faith in numbers.

Cephalometric analyses have significant, well-recognized deficiencies, and increased accuracy of measurements does not address them. There is, as yet, no evidence that increased accuracy from CBCT contributes to a change of treatment plan or better treatment. Even though such a notion might seem self-evident, one should consider that our treatment modalities are not so fine tuned to specific craniofacial patterns that a conventional cephalometric radiograph is inadequate to serve. Furthermore, identifying landmarks on CBCT images introduces significant errors that might mitigate the advantage of increased accuracy. Lastly, most of our diagnostic information is gained from clinical evaluations. The cephalogram serves as an adjunctive tool and has been shown to be superfluous in some circumstances, affecting treatment-planning decisions in some patients and to a limited degree.

**INCIDENTAL FINDINGS**

Incidental findings are no justification for radiographic exposure. The European guidelines on radiation protection state that “Routine radiography is unacceptable practice” and define a ‘routine’ or ‘screening’ examination as “one in which a radiograph is taken regardless of the presence or absence of clinical signs and symptoms.” If we put this recommendation to the side for a moment, CBCT undoubtedly provides many findings, although incidence varies. Price et al reported that 90% of all CBCT images examined had at least 1 finding, and 16.1% of the findings required further investigation. In contrast, incidental findings from conventional orthodontic radiographs seem much lower, although no direct comparison has been made. By far, the most common pathologic findings seen in CBCT images that could require intervention were carotid artery calcification and periapical osteitis. These are not outside the detection capabilities of the panoramic radiograph. Therefore, one should consider that a significant number of incidental findings in CBCT images (1) represent normal anatomic variants or are benign and do not require further intervention, (2) might already be known to the patient, (3) can be detected on traditional radiographic images, or (4) might be false-positive findings. In the absence of any signs or symptoms, the taking of CBCT images just in case an occult pathologic finding appears is not justified.

**COMPREHENSIVE EVALUATION**

Dr Larson seems to base his recommendations on the premise that a comprehensive imaging modality will prove useful on any occasion, so, why not take it from the start? After all, a CBCT image includes a cephalogram and a panoramic image for orthodontic assessment, and additional images for any potential periodontal evaluation, temporomandibular joint evaluation, temporary anchorage device placement, and airway analysis, plus the benefit of any incidental findings. More extensive diagnostic knowledge is assumed to lead to better treatment. This proposition is alluring but precarious and biased for several reasons. First, most of our patients are known not to have any of the problems listed, so extra radiation is used just to rule out additional incidental findings,
over those that would be found with a cephalogram and a panoramic radiograph. Second, if more diagnostic information is the goal, why stop at a CBCT? Why, to take it to the extreme, not perform a full-body computed tomography scan instead? Have we determined that a CBCT is the optimum choice in the risk–benefit balance? Third, in our quest for more information, why not perform other diagnostic tests that might be more relevant and do not incur a radiation burden? Such tests could include evaluation of thyroid and growth hormone levels, magnetic resonance imaging examination of the head (to assess temporomandibular joint disc position), measure the sizes of the muscles of mastication, examine the pituitary gland for adenomas, and evaluate the airway), nasal endoscopy or rhinomanometry, and bite-force measurement. Have we specifically selected large field-of-view CBCT based on evidence that it will result in better patient outcome than these other tests, or are we just using it because it is convenient? Fourth, with each diagnostic test comes more knowledge but also more false-positive findings that can lead to increased patient anxiety, unnecessary follow-ups, and further tests. Diagnostic evaluations should be focused and designed to answer specific questions, not be a fishing expedition.

CONCLUSIONS

As more research is conducted, and with continual improvements in technology, CBCT might prove valuable for all of our patients in the future. However, at the present time, evidence for the efficacy of CBCT imaging is lacking. Except for certain patients, replacing the conventional cephalometric and panoramic radiographs with a large field-of-view CBCT is simply overkill, potentially leading to a public health problem. It is the responsibility of the clinician to carefully select patients when CBCT imaging will provide a tangible benefit and resist the lure of technology for technology’s sake.

In response to the Steiner quotation: “Today, just like orthodontic radiography in the early 1900s, CBCT for orthodontic therapy is advocated by experts, without reliable evidence that the diagnostic technology is associated with improved patient outcomes.”

REFERENCES


