Indications and application

Digital Volume Tomography (DVT)

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Digital volume tomography (DVT), also known as cone-beam computed tomography (CBCT), has rapidly evolved since its introduction in 1997. Implant users have been a primary catalyst for these developments. Today they are reaping the benefits by obtaining three-dimensional images at high resolution (up to edge lengths of 80 µm per voxel in all three dimensions). These systems also offer excellent contrast ratios and minimized artefacts. They come with comprehensive software packages including options such as virtual implant planning, augmentation, volume/density measurements, and indeed virtual proposals for prosthetic restoration [1]. Current DVT systems have space requirements similar to panoramic x-ray systems. Radiation levels per scan vary with systems and exposure protocols, exceeding the radiation levels in panoramic radiography by factors ranging from 3 to 44 [2].

Numerous systems and system configurations are available, reflecting the broad spectrum of practical applications covered by this technology. Two general types of systems have prevailed: systems offering a maximized spectrum of applications, which would include conventional panoramic radiographs, and systems offering a convincing scope of performance and advanced software.

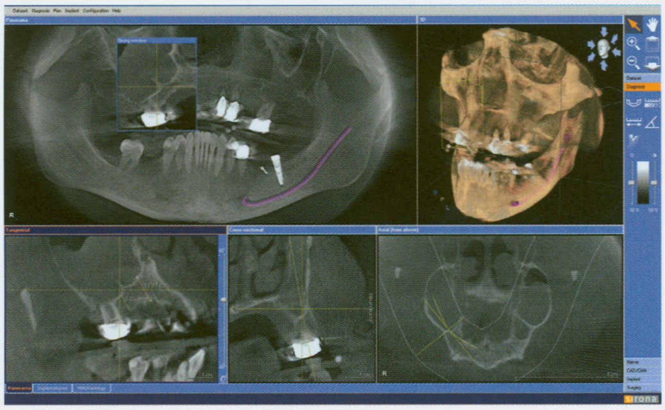
Given the multitude of aspects to be considered, oral implantologists are faced with the question what indications are clinically relevant and what features are needed to cover them. This article discusses the range of indications for DVT against a background of system features and practical considerations.

Volume size versus range of indications

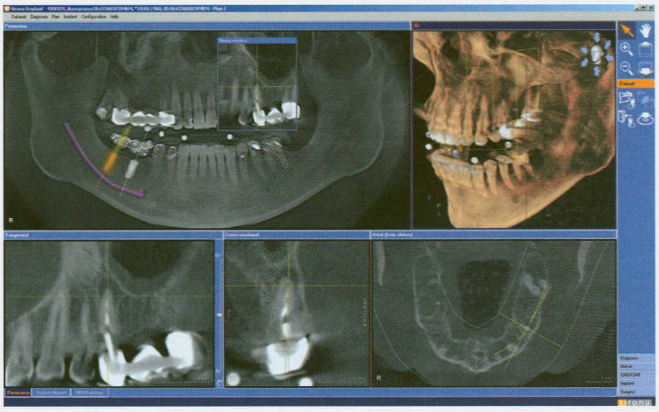
Volume size is the most important criterion for implantological applications. Cases involving the extensive placement of implants can only be visualized in images encompassing sufficiently large scan volumes. For example, fields of view (FOV) covering 5 x 4 or 8 x 8 cm will not suffice to visualize a dental arch in its entirety. This volume will be adequate to implement single-tooth implants, but several images may be required to cover multiple adjacent sites of tooth loss. This turns out to be a handicap especially when software for computer-assisted implant planning is used, since approaches of this type require both the proposed implant bed and the scanning template (including a reference) to be depicted in a single scan.

Larger volume sizes are also recommended for bone augmentation in atrophic jaws. For example, surgeons using grafting procedures with retromolar bone harvesting should be able to visualize not only the area of implant placement but also the donor site. Whenever procedures of this type are conducted in the mandible, it is indispensable to obtain an adequate view of the inferior alveolar nerve, both to avoid jeopardizing the nerve itself and to make sure that an adequately sized bone block is harvested. For bone augmentation in the maxilla, it is important to evaluate the sinus because any pathologic processes or potential septa should be identified. Septa are the most common cause of perforation of the Schneiderian membrane during preparation. Locating them accurately will therefore yield a crucial advantage in planning. An adequate scan volume is essential to reliably identify these implantologically relevant structures.

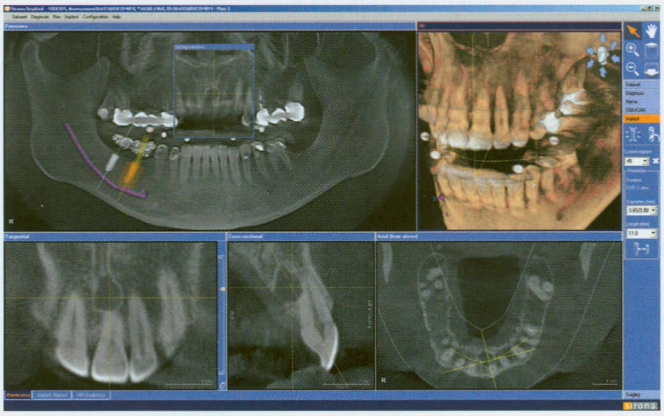
Furthermore, small volumes create a need for accurate patient positioning to capture specific areas of interest. Such positioning is not always easy to achieve; failed attempts will require another image to be taken, thus adding to the radiation load. What is more, recent measurements have shown that small-volume systems do not offer an advantage in terms of effective dose levels [2]. For example, images covering a FOV of 8.1 x 7.6 cm may create an effective dose burden of up to 652 µSv, while other systems will only require an effective dose of 70 µSv to yield a FOV of 15 x 15 cm [2]. Again, there is a need to weigh risk against benefit, as x-ray regulations almost any-



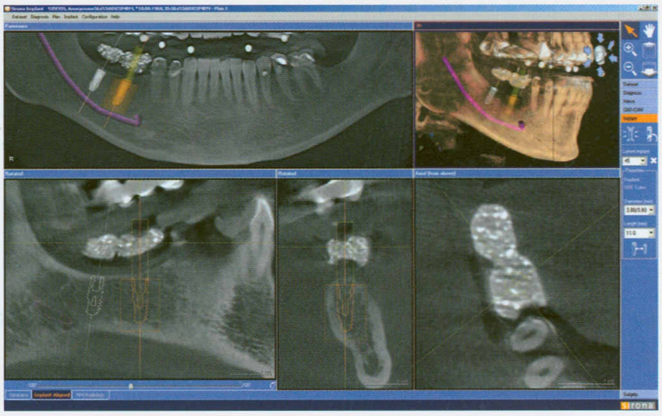
View of a sufficiently large volume record for implant planning. Note the presence of septa and extensive radiopacities in both sinuses. Also note the path of the inferior alveolar nerve (marked on the right side).



Data record for implant planning conducted with a scanning template and radiographic markers (round radiopaque structures in the inter-occlusal space). The record yields a number of incidental findings. Tooth 25 displays an apical radiolucency, with the transversal section (bottom centre) exhibiting a poorly instrumented root canal (helical preparation). This diagnosis is not compromised by the metal artefacts present.



A nasopalatal cyst is evident in the palatal vicinity of tooth 21. Without a three-dimensional image, the initial diagnosis of the cyst and its clear description in terms of position/size could not have been accomplished. Removal of the cyst was indicated due to root erosion of tooth 21.



Implant planning ready to be implemented (same patient). Both the prosthetic planning (barium-sulphate scanning template) and the available bone volume have been taken into consideration. The implant view has a special orientation always centring on the implant. An elongated view of the implant axis (yellow cylinder) yields valuable information and facilitates the task of considering the restorative proposal. Furthermore, an adjustable safety margin is shown around the implant.

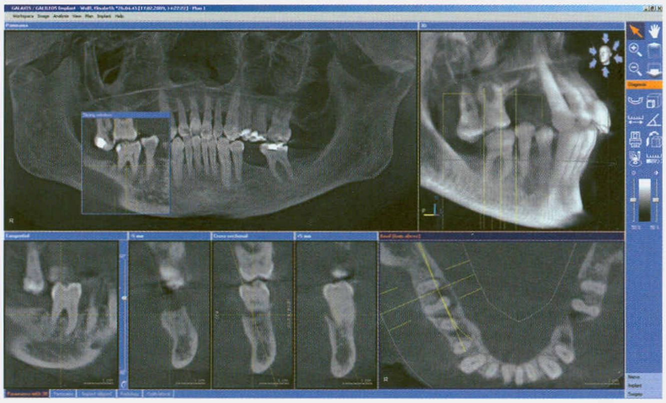
where call for each radiograph to be justified by an appropriate indication.

Conversely, it is also necessary to confine imaging to the area of interest with any systems offering larger volumes. For example, it is not usually necessary to visualize the maxilla if implants are placed in the mandible only. Large-volume systems should therefore offer useful masking options that will permit the maxilla and mandible to be scanned separately. At the same time, the task of patient positioning should be kept simple and reliable. Another point regarding volume size arises from the requirement that findings need to be obtained and documented for all areas covered by the image. Consequently, masking is useful both to control radiation loads and to meet forensic requirements.

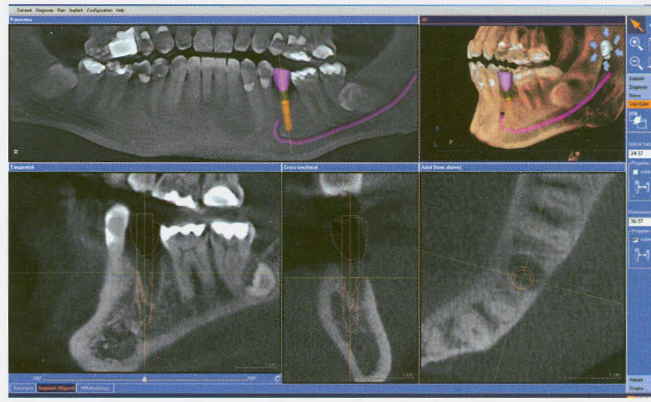
Adequate volume sizes are also needed to cover any additional indications pertaining to orthodontics, traumatology or sinus diagnostics [3-5].

Resolution versus tooth preservation

In addition to surgical indications, successful use of DVT has also been reported in endodontics and periodontology. Numerous studies have shown that the predictive value of dental charts is limited in periodontal diagnostics. Bony defects are masked by intact cortical or root structures; for another, thin bone lamellae may be overradiated in the event of unfavourable projection paths or overexposure [6]. Compared to the situation encountered during surgery, existing bone loss may be underestimated or



Three-dimensional analysis of a dentition with severely compromised periodontium. Both the three-dimensional (top right) and the axial (below) representation can be helpful in evaluating periodontal defects.



Implant planning based on Cerec and 3D radiographic data. Merging of both data sources eliminates the need for the technician to fabricate a radiographic template, and the result can be precisely visualized.

overlooked by the clinician. Limitations also exist in assessing oral and vestibular tooth surfaces, especially with regard to areas of dehiscence and fenestration [7]. Incorrect appreciation of the size and morphology of bony pockets is another factor.

DVT allows for three-dimensional assessment and interpretation of the periodontal condition. In this way, it becomes possible both to examine (single-wall, two-wall and three-wall) bony pockets and to classify the furcation involvement. It is reasonable to assume that radiographic diagnosis will reflect the clinical reality of horizontal and vertical bone loss more closely and enable the clinician to focus more specifically on any expected intraoperative findings [8].

Numerous applications have also been shown for endodontic users. In addition to outlining the geometry of root canals, DVT will yield information on periapical foci and allow for optimal planning of apicectomies [9].

While the range of indications is broadened by periodontological and endodontic use, these applications are conditional on technological requirements [10]. An essential requirement concerns the clinically attainable level of three-dimensional resolution. Today, resolution levels of < 150 µm can be regarded as standard. It is important to distinguish what is technologically possible from what can be attained in clinical practice. An essential question in this connection is how much the patient moves during scanning, as the DVT volume is actually computed from single images. If the patient moves, these single images will display the patient in different positions, hence the resolution of the overall scan will be reduced by the amount of movement.

From this follows that exposure time and resolution must be considered together. For example, numerous systems rely on longer exposure times for higher resolutions. However, the purpose of higher resolution can be defeated as the longer exposure time increases the chance of movement-related artefacts, which would effectively diminish the resolution. It is therefore important to minimize exposure times to obtain effectively high resolutions. Resolutions of < 150 µm are therefore not clinically attainable without rigid fixation of the patient. Because such immobilization is not always well tolerated, it is again necessary to find a clinically useful compromise. Attention should also be devoted to the rotational stability of the system.

Radiation dose versus image quality

In accordance with ICRP 2007, effective DVT doses currently exceed the doses applied for panoramic radiographs by 3 to 44 times. In absolute terms, the burden of one DVT scan ranges between 68 and 1073 µSv. Dose-reduced programs of computed tomography (CT) can reach dose levels up to 534 µSv [2]. Any claims that DVT scans are invariably less dose-intensive than CT scans are not tenable, as doses vary widely from system to system. That being said, many DVT systems do offer the desired advantage in radiation control by reaching levels < 100 µSv.

For numerous DVT systems, results of dose measurements have been published in the literature, thus offering users or potential users a scientifically sound basis for comparison. Manufacturers are naturally keen to extol any merits of low radiation exposure, so systems that have been commercially available for extended periods without any data on the results of dose measurement being available (or being made available) are likely to involve high dose levels. Since current systems do not show a direct correlation between volume sizes and dose levels, systems offering larger volumes will generally do better in this respect.

Another question is whether dose levels correlate with image quality, since low dose performance is known to be associated with smaller contrast ratios. No evidence for such a correlation has been reported in the literature, not least because image quality is influenced by a number of factors. Users should therefore make their own comparisons to see what impression they get from different images.

A disadvantage of DVT technology is its susceptibility to metal artifacts [11]. As a result, there is no way – even at high dose levels – to reliably identify any carious decay in already restored teeth. Owing to the high density of restorative dental materials, these are not readily pervaded by x-rays in diagnostic quality. The resultant cancellation artefacts will enter the DVT records as black areas adjacent to any restorations or implants. This also means that peri-implantitis cannot be reliably diagnosed with the help of DVT, since the implant will routinely be associated with circumferential artefacts in the images. On the other hand, DVT is excellently suited to determine the position and orientation of implants after placement, thus gaining considerable importance in the management of complications.

Software versus efficiency

Attention should be paid to software considerations because it is essential for complex imaging systems like DVT to offer convenience of operation. For software to be clinically useful, it needs to process the additional information gained by three-dimensional imaging in such a way that clinicians will not have any problems familiarizing themselves with the system and documenting all relevant information. Numerous systems have the disadvantage of requiring additional software packages to utilize the entire scope of performance.

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Systems offering diagnostic functions while requiring additional modules for implant planning have turned out to be less than efficient in clinical practice. Time-consuming routines for data imports and exports, for example, will prevent the clinician from informing the patient "on screen" of any planning options instantly after conducting the scan, although this option has proved extremely valuable in daily clinical practice. Care should also be taken that the software is expandable and open to integration with future developments. Therefore, system providers also offering CAD/CAM systems are clearly at an advantage. There have been preliminary reports on combined CAD/CAM and 3D radiography systems that can be used to develop virtual proposals for prosthetic restoration and will also permit chairside fabrication of drilling templates [12].

Summary

DVT systems have an important role in diagnosis and implant planning. They offer three-dimensional images without superimposition, real-size measurements at sub-millimetre accuracy, and good image quality. At the same time, their radiation levels are relatively low. DVT scans are routinely – but not mandatorily – indicated for preoperative implant diagnostics. Important factors to be considered include resolution and volume size, but also the requirement of clinically useful software, which will facilitate diagnosis and planning.

Fields of application for DVT include oral surgery but also periodontology and endodontics. These applications, however, require an adequate level of resolution to disclose even minute details. For the benefit of patients, care should be taken to use this technology only for appropriate indications and to strike an optimal balance between dosage administered and information gained. ■

A list of references can be found on www.teamwork-media.de