Intra-oral and panoramic images are not 3-D and clinicians can obtain only vague measurements from them owing to magnification changes due to positioning. In addition, they are not efficient for viewing certain pathologies. In response to these limitations, CBCT 3-D imaging technologies were developed. CBCT 3-D captures a volume of data and, through a reconstruction process, it delivers images that do not contain magnification, distortion and/or overlapping anatomy.

In recent years, CBCT 3-D has begun to make significant inroads into every discipline in our dental profession, expanding the horizons of clinical dental practice by adding a third dimension to cranio-facial treatment planning. CBCT uses advanced 3-D technology to provide the most complete anatomical information on a patient's mouth, face and jaws areas, leading to enhanced treatment planning and predictable treatment outcomes.

Essentially, this represents a paradigm shift, where measurements and anatomical relationships are precise and provide practitioners with a clear understanding of their patients' anatomical relationships. According to dental practitioners using this technology, it helps them perform treatment more efficiently. Regarding oral implantology, it is estimated that growth in implant-based dental reconstruction products will outstrip all other areas of dentistry, according to Kalorama Information. The traditional method of replacing a tooth with a dental bridge has been shown to be problematic, and more permanent solutions are urgently needed.

With a rapidly ageing population in the developed world and the resulting enormous demand for dental implants, CBCT 3-D imaging is becoming indispensable in oral implantology.
need for dental restoration, a large number of companies have seen the opportunity to adopt these sophisticated dental techniques. And indeed, as some have predicted, the growth in dental implant based procedures has increased considerably in recent years.

As a result, there has been a rapid increase in the number of practitioners involved in implant placement, including specialists and generalists, with different levels of expertise. At the same time, a number of unusual complications associated with these procedures have arisen. A literature and web search revealed several published reports of such complications, which include implant fractures (Fig 1), impingement on adjacent teeth (Fig 2), perforation of the lingual undercut (Fig 5), sinus perforations (Fig 4) and implants displaced into the maxillary sinus (Fig 5).

The clinical management associated with some of these complications is difficult at times and considered very invasive. Therefore, while the quantitative relationship between successful outcomes in dental implant treatment and CBCT-based dental imaging is unknown and awaits discovery through large prospective clinical trials, I strongly believe that using CBCT and 3D-based dental imaging is becoming a reliable procedure from a precautionary standpoint based on a series of recent preliminary clinical studies and case reports.

I also strongly believe that by taking 3D CBCT images prior to placing dental implants, many of the above-mentioned complications can be circumvented.

‘The clinical management associated with some of these complications is difficult at times and considered very invasive’

Reference

About the author

Dr Dov Almog is a prosthodontist with more than 30 years of diversified professional experience in clinical, academic and research environments. His publications include articles on CBCT, dental implants, carotid artery calcifications and practice management. In 2005, in acknowledgment of his research on incidental findings of carotid artery calcifications on panoramic radiographs, he received the Arthur H. Wuerthner Award from the American Academy of Oral and Maxillofacial Radiology. Dr Almog currently serves as chief of the dental service for the VA New Jersey Health Care System of the US Department of Veterans Affairs.
The human body encompasses more than 200 different types of cells, which are organised into tissues and organs that perform all the tasks required to maintain the viability of the system and reproduction. In healthy adult tissues, the cell population size is the result of a fine balance between proliferation, differentiation and cell death.

Following tissue injury, cell proliferation begins to repair the damage. In order to achieve this, quiescent cells (dormant cells) in the tissue become proliferative or stem cells are activated and differentiate into the appropriate cell type needed to repair the damaged tissue. Research into stem cell is inspired in the desire to understand how the tissues are maintained and repaired in adulthood and how so many cell types can be derived from human embryos.

It has long been observed that tissues can present a wide variety of cells and in the case of blood, skin and the gastric lining, the differentiated cells possess a short half-life and are incapable of renewing themselves. This has led to the idea that some tissues may be maintained by stem cells, which are defined as cells with a huge renewal capacity (self-replication) and the ability to generate daughter cells with the capacity of differentiation. Such cells, also known as adult stem cells, will only produce the appropriate cell

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lines for the tissues in which they reside (Fig 1).

Not only can stem cells be isolated from both adult and embryo tissues, they can also be kept in cultures as undifferentiated cells. The embryo stem cells have the ability to produce all the differentiated cells of the adult. Their potential can therefore be extended beyond the conventional mesodermal lineage to include differentiation into liver, kidney, muscle, skin, as well as cardiac and nerve cells (Fig 2).

The recognition of the stem cell potential unearthed a new age in Medicine - the Regeneration Medicine Age. It has made it possible to consider that an otherwise lost organ or damaged tissue could be regenerated. Because the use of embryo stem cells stirs up ethical issues for obvious reasons, most scientific studies focus on the applications of adult stem cells, although these are not considered as versatile as the embryo stem cells, since most researchers regard them as multipotent, i.e. capable of giving rise to some types of specific cells/tissues, whereas the embryo stem cells can differentiate into any and all types of cell/tissue groups. With the advance of scientific research, some tissues were noted to have greater difficulty regenerating, such as the nervous tissue, whereas bone and blood, for instance, are considered more suitable for stem cell therapy.

In dentistry, the pulp from deciduous teeth has been thoroughly investigated as a potential source of stem cells with promising results. However, the regeneration of an entire tooth, also known as THIRD DENTITION, is a highly complex process, which despite some promising results with animals, remains very far from clinical applicability. The opposite has been observed in the area of jawbone regeneration, where there is a higher level of scientific evidence on its clinical applications. Currently, adult stem cells have been harvested from some tissues, such as bone marrow and fat.

Bone marrow is regarded as a hematopoietic organ, i.e. capable of producing all the blood cells.
Since the 1950s, when Nobel Prize winner Dr E. Donnell Thomas demonstrated the viability of bone marrow transplants in patients with leukemia, many lives have been saved using this approach for a variety of immunological and hematopoietic illnesses. However, the bone marrow contains more than just hematopoietic stem cells (which give rise to red and white blood cells as well as platelets, for example), it is also home to mesenchymal stem cells (which will become bone, muscle and fat tissues, for instance) (Fig 3).

Bone marrow harvesting is carried out under local anesthesia using an aspiration needle through the iliac (pelvic) bone. Despite requiring a competent doctor to perform such task, it is not regarded as an excessively invasive or complex procedure. It is also not associated with high levels of discomfort either intra- or post-operatively. (Figs 4a-b).

Bone reconstruction is a challenge in dentistry (also in orthopedics and oncology), since rebuilding bony defects caused by trauma, infections, tumors and dental extractions requires bone grafting. The lack of bone in the jaws may impede the placement of dental implants, thus adversely affecting patients’ quality of life. In order to remedy bone scarcity, a bone graft is traditionally harvested from the iliac region (or the angle of the mandible. If the amount required is too large, bone from the skull, legs or pelvis may be used. Differently from the bone marrow, the process involved in obtaining larger bone grafts is often associated with high levels of discomfort and, occasionally, inevitable post-operative sequelae (Figs 5a-c).

All the problems related to bone grafting have been encouraging the use of bone substitutes (synthetic materials, human or bovine donors). However, such materials show inferior results compared to autologous bone grafts since they lack autologous proteins. Therefore, in critical bony defects, ie those requiring specific therapy to recover its

Fig 8b. Computerised Tomography of the rabbit skull after bone-sparing grafting with stem cells (note how the bony defect has practically resolved).

Fig 10b. Histological image of the site grafted with bank bone combined with bone marrow (note the presence of considerable amounts of mineralised tissue).

Fig 5b. Bone block from a musculoskeletal tissue bank associated with a bone marrow concentrate.

Fig 9a. Bone marrow

Fig 9b. Bone marrow homogenization in buffer solution (laminar flow).

Fig 9c. Bone marrow transfer into a conical tube in sterile environment (laminar flow).

Fig 10a. Bone marrow

Fig 11a. Histological image of the site grafted with bank bone combined with bone marrow (note the presence of considerable amounts of mineralised tissue).

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Evidently, despite the bone marrow stem cell techniques for bone reconstruction being close to routine clinical use, much caution must be exercised before indicating such procedure, as it demands an appropriately trained surgical and lab team, as well as the availability of the necessary resources (see images taken during lab manipulation of marrow stem cells at Sao Leopoldo Mandic Dental School) (Figs 11a-h). Similar studies performed in humans have been reinforcing the finding that bone marrow stem cells improve the repair of bone defects caused by trauma, dental extractions or tumors. The histological images below illustrate the higher potential of bone-sparing materials when combined with stem cells for bone reconstruction (Fig 9). It is clear that the level of mineralised tissue is significantly higher in those areas where stem cells were applied. (Figs 10a-b)

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Until very recently, my patients would have considered undergoing complete treatment including a ceramic crown or a bridge in one visit science fiction. The science of CAD/CAM technology has progressed at a staggering pace, enabling me to treat a case that represents a new level in the field.

This case report demonstrates a procedure that allows the treatment of a patient who has lost a tooth or had one extracted. In one visit, he or she can receive an implant using a while-you-wait, made-on-demand implant guide. Furthermore, modelling of the individual abutment or placing of a solid titanium abutment with a temporary crown, or a permanent ceramic crown, based on the indication and diagnosis, can be performed in the same visit.

The implant guide that is produced while the patient waits (CEREC Guide, Sirona) speeds up the entire process, owing to a precisely mapped location in a 3D CBCT scan using GALAXIS and GALILEOS Implant (both Sirona) visualisation software. Moreover, it also enables implantation using the flapless technique. Immediate fabrication and use of the implant guide is even more important in immediate implant placement after extraction of multi-rooted teeth, for which freehand implantation is extremely difficult.

In addition to CEREC Guide, we can order and use the CLAS-SICGUIDE (SICAT), made on the basis of a conventional impression, or OPTIGUIDE (SICAT), a stent that is manufactured without bite plates and impressions, requiring only a digital scan of the patient’s mouth with CEREC AC (Sirona) and a CBCT scan of the patient’s jaws (using GALILEOS or ORTHOPHOS XG 3D). Of all three guides that could be used, a pilot drill, sleeve in sleeve or completely guided stents, only CEREC Guide can be produced in-office immediately. CEREC Guide was used in the following case report.

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Clinical case report

A 55-year-old male patient refused orthodontic treatment to move tooth 13 into proper position while making space for a replacement of tooth 12. The patient had been chewing on primary tooth 55, which was extracted about 14 days before implantation. Figure 1 shows the gap after extracting tooth 53. Tooth 12 was missing and tooth 13 had moved mesially into the space (Fig 2). Overall, the patient was healthy and had no hereditary disease.

In this case, we began the treatment by taking a conventional impression of the jaw in which we were considering placing an implant to replace a missing tooth. We used quick-setting plaster well suited to fabricating the stone model (Fig 3). We placed a reference body in the location of planned implantation on the stone model to determine the correct size (three sizes are available: small, medium and large). The reference body should be placed against the adjacent teeth and fill the gap with the largest possible area but it should not become lodged between the adjacent teeth during placement. Once we had determined the optimal size, we wet the stone model with water and applied thermoplastic stent material softened with warm water to cover one to two adjacent teeth on each side ideally. The properly heated stent compound appears to be glassy/transparent, which by its transparency also indicates plasticity interval. Once the colour changes to opaque, setting has begun. While the stent compound was still warm and adapted to the stone model, we inserted the reference body (medium in this case; Fig 4). When the thermoplastic is still clear, it is possible to observe and review how the reference body relates to the edentulous space. Corrections can still be made until the material becomes opaque. Undercuts on the stone model can be blocked out before using, for example, a composite compound (not wax) to allow easier detachment of the thermoplastic stent material with the reference body from the model. Personally, I do not block out undercuts to ensure the most accurate mounting. Even in the ensuing test in the patient’s mouth, one must hear the characteristic click sound.

Once satisfied with the placement and retention of the stent with the reference body in the patient’s mouth, we captured a
CBCT scan of the patient using GALILEOS or ORTHOPHOS XG 3D. One needs to ensure that the large fiducial-containing portion of the reference body faces orally as depicted in Fig 4 and not buccally in ORTHOPHOS XG 3D, as there may be a tendency to cut this portion off in its 8cm×8cm field of view. While waiting for the image to load on the PC, we scan the implant space layout on the model using an intra-oral scanner (CEBEC AG) and software modelling of the proposed crown follows, in terms of suitable shape, size and location in the future implant position.2

Once the CBCT scan has loaded, we open the GALAXIS software and begin the planning. The first step is to insert the exported CEREC crown proposal in *.ssi format because this is the only CEREC crown proposal format that GALAXIS software can read (Fig. 5). The exact placement of the proposed CAD/CAM crown in the CBCT scan will allow precise read-out of borders between hard and soft tissue (Figs 6-8) and the digital implant placement under the crown in such a way that the future connection of the implant and crown using an abutment is prosthodontically possible (Fig 9). After the digital implant had been imported into GALAXIS, the need to use CEREC Guide (or another guided-surgery technique) became apparent in this case owing to a dramatic conical apical narrowing of the roots of the adjacent teeth 14 and 15 in the intended implant space (Fig 10). Owing to the lack of space between these roots, we chose a 3.5/8mm implant (SwishPlus, Implant Direct). After digital implant placement, we select to continue and edit the sleeve system. After selecting this option, a new dialog box marked “reference body” appears. On this screen, we mark the fiducial points using the lever underneath the image and move the lever until the fiducials appear to be as round and clear as possible. Finally, we double click on the three most clear fiducial points and the software will then automatically search for and determine the remaining fiducials (Fig 11). Next, we confirm that the fiducials have been found and the reference body appears on the 2D and 3D images (Fig 12). In order to better visualise the interaction of the drill path and drill body with the implant, the final drill path and pilot drill path must be turned on in

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the 2D views (Fig 15). The reference body must fit exactly within the drill path in order to be milled.

The most important part of CEREC Guide production is setting the D2 value. The D2 value, also known as the drill stop length, is the distance from the apex of the implant to the top of the guide. If we measure the length of the drill from its cutting tip to the drill stop, the D2 value will be that length minus 1mm, which is the thickness of the implant guide handle. In our case, for the 8mm implant, this value was 24mm minus the 1mm handle. The D1 value changes with the D2 value automatically (Fig 14).

In order to continue, we export this arrangement data back to the CEREC AC unit as a *.cmg or *.dxd file. After opening the correct file in CEREC Software 4.xx, the drill body proposal will appear in the milling preview (Fig 15). Now we can place the appropriate block size (in our case this was “M”) into the milling unit (MCXL on inLab MC XL, Sirona) and select “mill”. Milling time is approximately 12-16 minutes (Fig 16). We break the drill body out of the block and remove the sprue carefully.

Next, we remove the reference body from the thermoplastic stent and, using a scalper or bur at a very low speed; cut away a thin layer of the thermoplastic material from the bottom of the guide to allow the drill to pass through the guide. When snapping the drill body onto the thermoplast stent, it is important to ensure that the drill body is inserted with the correct vestibulo-oral orientation (Fig 17).

Sirona produces specific guide handles for each block size (again in small, medium and large) and for several implant guide kits. In our case, we used the guide handles for Straumann for the next step because these handles are compatible with the Implant Direct implant used.

Surgery
We begin with anesthetising the tissue around the work area and placing the cleaned and disinfected CEREC Guide in the mouth, followed by the fit evaluation. The guide should feel secure and not move over the teeth. As we performed the flapless technique, we began by punching the tissue with the appropriate puncher (Fig 18). We then removed the guide and easily separated and removed the punched tissue (Fig 19). We placed the CEREC Guide back into position and continued with subsequent drills and guide handles.

Using the guide kit for Straumann (Sirona CEREC Guide Drill Key Set ST), we started with the M 2.2 handle and 2.2mm pilot drill (Fig 20), followed by the M 2.8 handle and 2.8mm drill (Fig 21). Finally, we removed the CEREC Guide and inserted the 3.5/8mm SwishPlus implant without the guide, that is, freehand (Fig 22).

Temporary
We screwed a solid abutment (Implant Direct; Fig 23) into the inner part of the implant, and covered the screw-hole with Teflon. This was immediately followed with an intra-oral scan. As scanning powder cannot be used for an unhealed soft-tissue margin, we used the new powder-free CEREC Omnicam camera. Next, we proceeded through the steps of CEREC Software 4.xx (Fig 24) to mill the temporary crown from a LAVA Ultimate block (3M ESPE; Fig 25). While it is acknowledged that dentistry is not Formula One, the patient was very satisfied with a total treatment time of 115 minutes.

Conclusion
This case report has demonstrated the workflow and manufacture of CEREC guides. Anyone interested in this procedure and its processes is invited to visit our training centre in the Czech Republic, where one can view patient surgeries live and participate.