It appears that there is still a great divide between those who utilise 3-D technology for dental implant planning and surgical placement of dental implants and those who do not. Clearly, decisions as to how to diagnose and treatment plan our patients may be the difference between success and failure. Recently an internet advertisement promoting an educational programme stated that 'Implant surgery is not complicated, easier than most other dentistry, and every dentist has the skills to surgically place implants. If you can take teeth out, you can put a dental implant in! You don’t need expensive equipment for brain-guided surgery, you can learn it with no initial investment!' Implant dentistry has become one of the most predictable and successful treatment modalities in all of dentistry. If the only imaging modality utilised is a two-dimensional panoramic or periapical radiograph how can a clinician really know if a procedure will be complicated?

Figure 1 represents a beautifully rendered 3-D maxilla and mandible with the cross-sectional imaging showing the existing teeth and roots in both arches as processed within the interactive treatment planning software (NobelClinician, Nobel Biocare). This vital information allows for a complete understanding that each patient’s anatomy is individual and unique, and that each patient’s bony anatomy, root positions within the bone, and tooth trajectories may not coincide with the alveolar process. Therefore without this information, the placement of implants may be compromised, resulting in complications. Therefore it is imperative that clinicians utilise the most up-to-date 3-D CBCT imaging and interactive treatment planning software to fully appreciate the individual nature of each patient’s unique anatomy.

When evaluating potential implant receptor sites, it is not just the available bone that should be considered, as our patients are in need of teeth, not implants. Clinicians must learn to practice ‘restoratively driven implant reconstruction’—knowing where the tooth position should be in relation to the bone and potential implant. This process can be accomplished with greater accuracy with the use of 3-D imaging and software applications that have the tools to provide clinicians with this valuable diagnostic information.
There are advertisements that promote concepts such as: ‘Brain-guided surgery vs cone beam-guided surgery—which works better’, leading clinicians to believe that it is the computer that makes the decisions, and not the clinicians who use the technology properly to improve their diagnostic abilities.

The diagnostic and treatment planning process using CBCT imaging provides for a variety of views including the axial, cross-sectional, panoramic, 3-D reconstructed volume (Fig. 2), and much more afforded with the use of interactive software as an aid to evaluating the thickness of the buccal plate, to assess the bone density, to visualise the trajectory of the tooth vs the bone, and then if a receptor site is found to be appropriate the clinician can position the implant to best support the desired restoration (Fig. 3).

Therefore it is the clinician who will decide on the available treatment options based on the enhanced diagnostic information provided by the technology. 3-D imaging technologies help clinicians diagnose more accurately and more consistently, than any two-dimensional modality—there is just no comparison. Diagnosis is the key element of implant success, and should not be minimised. To diagnose properly, clinicians need to use our brains—it is not the computer that makes the decisions.

Case presentation

A 74-year-old male presented to the clinic with a chief complaint of pain in the edentulous lower jaw, especially on the right side when trying to masticate using an existing complete denture (Fig. 4). The denture had little or no retention due to the resorbed condition of the mandibular arch, and was almost impossible to wear without denture adhesive applied many times during the day. The patient had been seen by a local dentist with the concept of managing his mandible with the placement of dental implants.

The initial treatment options that could be considered for this patient included:

- Four/five standard diameter implants supporting a fixed hybrid restoration.
- Immediate loading of implants with a fixed restoration.
- Two standard diameter implants supporting an overdenture.
- Four standard diameter implants supporting an overdenture.
- Narrow-diameter implants supporting an overdenture.
- Flapless surgical approach or a flap procedure to expose the underlying bone.
The original treatment plan conceived by the original treating dentist was to place four narrow-diameter implants in the anterior mandible to support the existing complete denture with overdenture attachments, due mostly to financial limitations of the patient. A flapless surgical protocol was chosen, and the initial implant site located by the panoramic radiograph.

The panoramic reconstructed view of the edentulous mandible may provide the clinician with some information regarding the bony anatomy, but it is not sufficient to plan for implants in the majority of case presentations. It is essential to precisely locate the bilateral anatomical sites where the inferior alveolar nerve exits the mandible, and the panoramic radiography cannot provide this information accurately. To plan for the placement of implants, it would be important to understand the available bone anatomy to determine the number of implants that could be placed, and the diameter and lengths required. The 2-D panoramic radiograph cannot predict the width, trajectory, or density of the bone, as well as the thickness of the overlying soft tissue. Therefore, it can be difficult for a clinician to make truly educated decisions based on two-dimensional imaging modalities.

Upon drilling the initial pilot osteotomy preparation directly through the soft tissue, the drill immediately broke ‘in the bone’. A periapical radiograph confirmed that the drill was broken, and deemed to be ‘in the bone’. The subsequent paper print-out of the digital radiograph can be seen in Figure 6. The clinician reported what happened to the patient, and decided to abort the entire procedure and send the patient to a nearby oral and maxillofacial surgeon. The surgeon examined the patient and decided to let the area heal, and follow-up later for a new plan of treatment. At this time a CBCT was performed by the oral surgeon to better assess the situation. The patient was not
pleased, lost confidence in the clinician, and sought another opinion.

The initial review of the CBCT data was remarkable in the depiction of the thin, sharp, knife-edged alveolar ridge (Fig. 7). The 3-D volumetric reconstruction also reveals the position of the bilateral mental foramina and inferior alveolar nerves (seen in orange).

Contrary to the 2-D view of the panoramic radiograph, 3-D imaging and interactive treatment planning software allow clinicians to truly understand the patient’s existing anatomy. For the example of the fully edentulous mandible, the CBCT scan revealed that the underlying bony ridge was quite sharp and uneven at the crest. This presentation would certainly not be favourable to place implants with a flapless surgical approach. In fact, to facilitate the placement of implants, and facilitate the restorative phase, it would be beneficial to flatten the irregular ridge to gain the appropriate and desired width at the alveolar crest (Fig. 8).

The CBCT data provides us with much more information and clinicians should consider ALL of the views afforded by the CBCT scan data and use the tools of the planning software to simulate the positioning of the implants, such as the axial and cross-sectional views. In fact, to facilitate the placement of implants, and facilitate the restorative phase, it would be beneficial to flatten the irregular ridge to gain the appropriate and desired width at the alveolar crest (Fig. 8).

In the planning phases, clinicians should be considered the engineers and architects of the oral cavity, providing a ‘blueprint for success’ based upon the data provided by the 3-D imaging, and the ability to simulate the implant position to avoid adjacent vital anatomy. The CBCT data can often yield significant surprises that cannot be determined with 2-D imaging. The initial assessment of the CBCT data revealed that the patient was not positioned properly during the scan acquisition. The inferior border of the mandible was not imaged. It is very important that patients be positioned properly to assure that all pertinent diagnostic information is available for review. Fortunately it did not impact the diagnostic phase for the purposes of implant placement.

The cross-sectional images revealed the presence of a thick facial buccal plate of bone in some areas, thinner in others, and a thick lingual plate of bone generally. The surprise was in the symphysis, a hollow area in the anterior central area exactly where implants would be placed! Other hollow areas and intraosseous vessels were noted (see arrows, Fig. 10). The ‘hollow’ areas in the anterior symphysis are as illustrated in the 3-D reconstructed volumes with four simulated implants in an occlusal view.

The hollows in the anterior symphysis area of the mandible are seen in a ‘clipping’ view with simulated implants, slicing through the 3-D volumetric reconstruction (Figs. 11a & b). This anatomical variation could not be determined with 2-D imaging modalities. Once this was known, the planning of implants could proceed with the knowledge of the individual patient’s anatomical presentation. The patient was informed of the issues related to the anatomy as shown on the 3-D simulation from the CBCT scan. These images are invaluable to educate the patient and improve case acceptance, and extremely invaluable for the diagnostic process in determining the best surgical approach. Proper diagnosis and treatment planning through 3-D imaging and simulation software revealed that the narrow ridge would have been a significant obstacle using a flapless approach, and the hollows in the bone may have caused signifi-

Fig. 17: Each of the four implants was measured for implant stability with the implant specific SmartPeg.

Figs. 18a & b: A resorbable calcium apatite bone grafting material was used to fill voids and cover the implant—followed by applications of platelet-rich fibrin (PRF).

Figs. 19a–c: Healed site at three months (a). Uncovering of the integrated implants, healing collars and SmartPeg to measure ISQ values postoperatively (b). SmartPeg measuring ISQ values at uncovering (c).

Fig. 20: Four overdenture attachments to support a complete mandibular denture.
Guided Implant Reconstruction

Case Report

Cant issues in the placement and the ability to stabilise the four implants that were eventually placed. Based on the CBCT data and interactive treatment planning simulations, it was elected to complete the surgical placement of four implants in the anterior symphysis in a ‘diagnostic-freehand’ manner. The anatomical landmarks were clear and allowed accuracy of implant positioning. The knife-edged ridge required a full flap surgical approach (Fig. 13).

The broken drill was immediately located lingual to the alveolar crest embedded in the soft tissue. Apparently the drill deflected off the sharp ridge into the floor of the mouth, and the torque caused the drill to break. Fortunately the drill did not cause any immediate complications as the floor of the mouth contains many vessels, which if perforated, could have resulted in a sublingual hematoma. The remaining broken drill as seen in Figure 14 was easily retrieved.

Once the offending element was removed, the plan was to reduce the knife-edged ridge to gain appropriate width for implant placement. The reduction was accomplished in a free-hand method based upon the position and location of the mental foramen on either side of the symphysis. Based upon a thorough review of the CBCT scan data the expected hollow area of bone in the anterior symphysis was exposed (Fig. 15).

Prior to implant placement, the soft tissue in the anterior symphysis was carefully removed with serrated curettes and serrated round burs. Following the simulated plan, osteotomies were prepared for four implants to support an overdenture. The two middle implants were 4.0 mm diameter by 13 mm in length, and the two distal implants were 3.5 mm by 13 mm in length approximately 1–2 mm below the bone crest as per manufacturer’s protocol (AnyRidge, MegaGen Implants). Each implant was well fixated due to three factors: (1) the anticipated thickness of the buccal and lingual cortical plates; (2) the apical length of the implants engaging native bone; and (3) the thread design of the implant type (Figs. 16a & b).

Each implant was tested by resonance frequency analysis (RFA) to document implant stability with an implant-specific SmartPeg to record an implant stability quotient (ISQ) value (IDx Osstell). Clinicians might consider the importance of assessing implant stability for every implant placed using a non-destructive and objective protocol well-documented in the scientific literature. Additionally significant and differing entirely from insertion torque values is that ISQ values can monitored over time which is especially important when a two-stage surgical approach is anticipated as in this case example.

To fill the voids around the implants and over the alveolar crest, a small particle sized synthetic resorbable calcium apatite grafting material was used (OsteoGen, Impladent Ltd.; Fig. 18a). The implants were then buried under layers of platelet-rich fibrin (PRF), and the soft tissue approximated to cover the site with tension-free closure (Fig. 18b). Post-operative healing was unremarkable.

After the site was allowed to mature for three months, a midline incision carefully split the narrow band of keratinised tissue to uncover the grafted site and the underlying four implants, which were all covered with a small layer of immature bone. Once fully exposed, each implant was once again fitted with a SmartPeg to assess an ISQ value, which was then compared with the initial values to determine the progress of osseointegration and to confirm implant stability (Figs. 19a & b). The ability to measure stability over time provides invaluable information for the clinician about the health of each implant. A favourable ISQ value imparts a level of confidence and knowledge of when an implant can be loaded and restored. Healing collars were positioned to allow for the soft tissue to be approximated and sutured.

The patient’s initial desire was to help relieve the pain associated with a denture that was not retentive due to the topography of the arch and proximity of the mental nerve to the alveolar crestal bone. The restorative phase continued with the impression phase, and placement of overdenture abutments to secure

Fig. 21: PreForm software designing supports to fabricate two separate mandibular models.
Figs. 22a & b: The virtual surface model (a), and the actual 3-D printed model (b).
the denture and prevent pressure on the nerve. The limitation of available keratinised tissue was initially managed to the comfort and cleansability for the patient.

At the time of implant placement, the RFA/ISQ values were recorded. The initial values were actually acceptable if immediate loading was desired (over 70), based upon the excellent stability afforded by the thread design of the implant engaging the buccal and lingual cortex, and apical length into native bone. A two-stage approach was elected due to the large hollow areas in the symphysis, which were grafted and covered with PRF. At three months, the implants were found to be covered with a thin layer of immature bone, and the intermedullary area seemed solid. A second series of measurements were recorded to reflect the status of integration. All values increased significantly, verifying that the process of osseointegration was progressing positively, and loading was appropriate. Overdenture abutments (Meg-Rhein) were secured to each implant, and stainless steel housings with retentive caps were embedded into the denture.

Discussion

As technology becomes more available to clinicians worldwide, our ability to diagnose and plan with improved accuracy and consistency can only be seen as a huge benefit. The use of 3-D printing has now become an affordable option for both group practices and single practitioners, therefore making it possible to produce accuracy biomedical models that greatly enhance the diagnostic and treatment planning phase. DICOM data can be exported to standard files that can be managed in software that drives 3-D printers to fabricate models of the mandible or the maxilla. The CBCT dataset from the case presentation contained within this article was exported as a standard triangulation language (STL) file and imported into the 3-D printer software (PreForm Formlabs; Fig. 21).

The importance of having an actual model in-hand cannot be underestimated. For this particular case presentation, the 3-D printed model was fabricated using a process known as stereolithography by an in-office 3-D printer, the Form 2 (Formlabs). The surface detail is excellent, and provides not just an excellent diagnostic aid, but a method to educate our patients on the recommended treatment plan based on a physical model that can be viewed and touched. It has been demonstrated that these models can be successfully used for guided surgery applications, and for other bone grafting guides such as a ‘sinus-lift’ or ‘harvest’ guide. The virtual 3-D reconstructed surface model can be seen in Figure 22a, and the 3-D printed model in Figure 22b. The position of the bilateral mental foramina can be clearly seen, as well as the intramedullary bone within the ramus, and the anterior symphysis where the hollow areas were noted. These models can also be utilised to simulate the actual surgical approach to validate the procedure and for surgical guide fabrication.

This singular case illustrates many important aspects about treatment planning for dental implants. To minimise the diagnosis phase, and to suggest that clinicians do not need to use ‘expensive’ equipment as an aid to implant planning is not appropriate in today’s world of the digital workflow where we need to avoid complications to insure that we offer our patients the correct treatment. Some have suggested that technology is used in place of sound thinking, or that the computer makes the decisions for the positioning of the implants. To suggest that when we use computers to help plan the case that we are not using our brains, or that computers are making the decisions about where implants are placed is an incorrect assessment of the state-of-the-art.

Technology, when used properly, expands our brain power by providing clinicians with the necessary information to make educated decisions for our patients. To negate the use of technology due to perceived ‘increased costs’ or that 2-D radiography is sufficient for implant planning is a potentially dangerous approach—relying on 2-D imaging requires guesswork, and there is no place for guessing when drilling into bone. Whether clinicians use ‘guided’ surgery, use surgical templates, or place implants totally ‘freehand’, it is important that our minimal standards be to use 3-D imaging and interactive treatment planning software applications to provide a ‘blueprint for success’, to avoid complications, reduce morbidity, with the ultimate goal to help facilitate the restorative phase that provide patients what they want, teeth. Remember: ‘It’s not the Scan, it’s the Plan’!

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**Table 1:** RFA/ISQ values over time.

<table>
<thead>
<tr>
<th>Implant Site</th>
<th>At Placement</th>
<th>3 months</th>
<th>6 months</th>
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<tr>
<td>1</td>
<td>78</td>
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<td>2</td>
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</tr>
<tr>
<td>4</td>
<td>71</td>
<td>84</td>
<td>84</td>
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</tbody>
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