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Why education?

As the use of cone beam computed tomography increases worldwide, so has the need for proper education on what this imaging modality represents. We, as clinicians, no longer live in a two-dimensional world... as three-dimensional technology surrounds us all, every single day. However, do we really know what we need to know about to use this imaging modality properly?

When we upgrade to a new smartphone, such as Apple's iPhone or any other brand that promises a multi-mega-pixel camera, improved video resolution, an endless supply of 'apps', texting, FaceTime, Bluetooth connectivity, etc, do we actually spend time reading the manual to learn how all of the new and improved features work? Are we even aware that a manual exists? When we have a problem with our new smartphone, when we cannot figure out how a special feature works, what can we do? If you go online and search for the answer, it may exist in the form of a posting from a knowledgeable source, or perhaps there is a link to a YouTube video where someone has taped a step-by-step description of how that special feature works. The same applies to that new digital camera you may have purchased, or received as a gift. How do you know how to change from a 4:3 aspect ratio, to 16:9, or the panoramic layout to take that perfect picture, and then once the photo is taken, how do you manage to get the image from the camera to your computer, or to a printer so that you can have a hard copy of that perfect picture? Who is teaching us how to manage technology today? Or are we just managing to learn only the very basic commands to allow us to function appropriately in our everyday lives? Are we only using a small percentage of the power that technology offers?

When we, as clinicians, use the dataset from a CBCT scan, are we just managing with the basics of interpreting the DICOM data? Do we really understand the impressive capabilities of the interactive treatment planning software that is packaged with the machine, or software that exists on your laptop computer? The questions continue. Who is teaching us how to manage all of this new data that is delivered after each scan is taken? Where can we learn how to improve and maximize our skill set to properly navigate through the wonderful modality of 3-D imaging? How can we best expand our knowledgebase to provide our patients with the most state-of-the-art care?

One of the goals of our cone beam magazine is to showcase the variety of ways that clinicians can utilize CBCT technology. We hope that our loyal readers will continue to gain valuable information that can be directly applied to their daily practice. While it is a small step in the educational process, it is our desire to help motivate clinicians worldwide to try and learn as much about this technology as possible, to improve their skill set, go beyond the 'basics', and then help to educate others. It may be as simple as reading the manual, or using a cotton roll (see inside)!

Please enjoy this year's first issue of cone beam!

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Improved CBCT diagnostic acuity with the ‘Lip-Lift’ technique

Author: Dr Scott D. Ganz, USA

The use of three-dimensional (3-D) CBCT imaging has evolved quickly as the worldwide method of choice to aid in the diagnosis and treatment planning for dental implants, bone grafting, and a variety of other treatment modalities. As each patient presents with their own unique anatomical reality, it is the power of the interactive treatment planning software that helps to convert the CBCT data set onto the computer screen for interpretation and analysis. However, having a CBCT scan by itself may not provide the clinician with the most definitive appreciation of the patient’s anatomy as it relates to the proposed treatment. Often, to improve diagnostic accuracy, it is helpful to establish a relationship between the underlying bone and desired restorative outcome with a scannographic, or radiopaque template worn by the patient during the scan acquisition. After duplication of a diagnostic wax-up, or duplication of a patient’s denture with a radiopaque material (BariOpaque, Salvin Dental Specialties), the template prosthesis seated intraorally, and the scan acquired.

The radiopaque template as seen in the cross-sectional slice, reveals several important aspects of the patient’s anatomy (Fig. 1):
- the template seen in relationship to the underlying edentate alveolar maxillary ridge (red arrow)
- the flange of the denture template defines the superior extent of the labial vestibule (yellow arrow)
- the grey area surrounding the template and bone representing the soft tissue components

Fig. 1. Duplication of a patient’s denture with a radiopaque material reveals the relationship between the desired tooth position and the underlying bone.

Fig. 2. A cross-sectional slice of a maxillary anterior incisor tooth, showing: the outline of the lip (yellow arrows), the root apex (red arrow), and the exposed tooth root (pink arrow).

Fig. 3. The lip rests against the maxillary canine alveolar-tooth-root complex (yellow arrow). If an implant osteotomy follows the tooth socket, it can potentially perforate the thin facial cortical plate (pink arrows).
and the anatomy of the nasal cavity above the alveolus. For an edentulous or partially edentate patient presentation, the application of a radiopaque scanning template is an invaluable part of the diagnostic phase.

When teeth are to be extracted and implants placed, it is difficult to fabricate a radiopaque scanning template unless the teeth have been prepared to accept an acrylic transitional restoration. The appearance of the cross-sectional slice of a maxillary anterior incisor tooth can be seen in Fig. 2. The position of the tooth appears to be facial to the alveolus, which the author has termed as the ‘reality of anatomy’. The apex of the tooth gives the impression that it dehisces through the facial cortical plate of bone (red arrow). The facial aspect of the root appears to be approximately 4 mm above the alveolar crestal bone (pink arrow). The patient’s lip rests against the facial aspect of the alveolus and the tooth (yellow arrows).

A maxillary canine tooth on another patient presents a similar pattern in the cross-sectional slice (Fig. 3). The tooth root does not reside within the greatest volume of bone, at a different trajectory from the alveolus. This can lead to complications if an implant osteotomy is prepared within the actual tooth socket, potentially perforating through the thin facial cortical plate (pink arrows). Again, the lip rests against the alveolar-tooth-root complex, limiting the appreciation of the thickness of the soft tissue, and aiding to define the facial cortical housing (yellow arrows). In either cross-sectional example (Figs. 2 & 3), the extent of the labial vestibule cannot be determined.

The use of interactive treatment planning software adds advanced software tools to help remove scatter, improve the diagnostic capabilities, while creating three dimensional reconstructed volumes that can be seen in all planes of view. The ability to navigate and ‘slice through’ 3-D volumes, known as ‘clipping’, provides unprecedented visualisation of the maxillo-mandibular structures. A maxillary 3-D volume ‘clipped’ through the right canine (marked in red) is seen in Figs. 4a & b. The 3-D reconstructed volume helps to further define the maxillary alveolar anatomy, tooth, and root position within the bone. An advanced software feature allows for manipulation of the grey-scale density of the scan data (thresholding). This tool known as ‘segmentation’ can be used to reduce scatter from metal artifacts, such as crowns or fillings, and to separate one object from another. Through software segmentation, the maxillary right canine can be virtually extracted from the alveolus, illustrating the socket anatomy, the thin facial cortical plate (yellow arrows), and the palatal bone thickness (green arrow) (Fig. 5). The software allows the images to be enlarged for closer inspection (Fig. 6). Note the areas of good density and where the density is poor within the alveolus, superior to the root socket.

The capability to virtually remove a tooth and root from the bone can aid clinicians in making educated decisions regarding immediate extraction-to-implant placement, immediate-to-transitional restoration, and an appreciation of the potential ‘gap distance’, which may be present after implant placement. A simulated implant of the appropriate diameter and length can be positioned within the virtual socket to gain initial stabilisation as related to the desired restorative outcome (Fig. 7). The thin facial cortical bone can be clearly seen (yellow arrow), as can the thicker palatal bone (green arrow). The facial ‘gap’ between the implant and the facial cortical plate can be fully appreciated, and decisions made whether or not to fill the gap with bone (red arrows).

The diagnostic information from CBCT data can be significantly improved by taking one simple step prior to the scan, regardless of the software application, and without regard to advanced software tools. For almost two decades, the author has advocated the use of a ‘lip-lift’ technique: moving the lip away from the teeth with the use of a simple cotton roll (Fig. 8). Plac-
A cotton roll under the lip as demonstrated in the cross-sectional slice, brings the lip (yellow arrows) far enough away from the tooth, root and alveolus to fully appreciate the region of interest. The vestibule can be defined (red arrow), and the thickness of the soft tissue attached to the alveolus superior to the tooth root. The soft tissue biotype can also be seen as thick or thin (pink arrow), as well as the facial cortical bone. The enhanced diagnostic appreciation of the tooth-root-alveolar complex can help prevent complications when implants are placed parallel to the tooth socket (Fig. 9a). If the implant were to be placed as per the simulation in Fig. 9a, with an abutment trajectory projecting through the clinical crown (green), the implant would perforate into the incisal canal. If the desired restoration was to be a screw-retained crown, the screw-access hole would need to project through the lingual/palatal aspect of the crown, dictating a different trajectory for the implant (Fig. 9b). At minimum, the resulting implant position would require bone grafting to cover the exposed threads. Therefore, the trajectory of the tooth in relationship to the alveolar housing could not be confirmed without cross-sectional imaging, avoiding potential iatrogenic damage, or complications from a malpositioned implant.

Another clinical case that utilised the ‘lip-lift’ clearly illustrates the advantages of placing a cotton roll in the labial vestibule (Fig. 10a). The lip is positioned away from an area where a tooth had been lost (yellow arrows). A simulated implant is placed within the remaining alveolar bone with an abutment projecting (orange) through a radiopaque marker, which helped to define the desired tooth position (yellow outline). The facial thickness of the soft tissue can be appreciated and measured (pink arrow), as the shape of the remaining alveolus curved superiorly to the floor of the nose (red arrow). The incisal canal can also be seen (green arrow). Using only the outline of the simulated implant (green) and virtual tooth (yellow outline), inspection of the potential implant receptor site, thickness of the soft tissue (pink arrow) and adjacent vital structures can be greatly enhanced (Fig. 10b). The apical portion of the implant can be seen in close proximity to the incisal canal (green arrow). Ideally, in order to support the soft tissue emergence profile, a bone graft should be considered. However, it should be noted that without the actual abutment trajectory, the position of the implant may not provide the best aesthetic or functional outcome. The use of the ‘lip-lift’ technique in coordination with the interactive treatment planning software helps to define the volume of bone required to fill the defect to achieve optimal results (yellow outline) (Fig. 11). Measurements can be determined, and a decision can be made to obtain the projected volume of bone from an autologous source, bone bank allograft, processed xenograft, or synthetic material. In addition, understanding the shape and extent of the labial vestibule can aid in planning the flap design, and tissue release to obtain tension-free closure after graft/membrane placement.
Conclusion

The application of three-dimensional imaging has been greatly enhanced through the continued evolution and adoption of lower dosage CBCT devices. The image resolution and image quality have benefitted from improvements in sensors, graphics processors, increased computing power, and software applications. CBCT has become an essential tool for pre-operative assessment of potential dental implant receptor sites, bone grafting procedures, and other oral surgery applications. The diagnostic power of the imaging modality has been greatly augmented by newer and upgraded tools included in interactive treatment planning software applications.

The important tools include (but are not limited to):

- availability of realistic virtual implants
- library of abutment components
- advanced software segmentation/thresholding
- clipping functionality
- 'selective transparency' as defined by the author
- and calculation of bone graft volumes.

Despite all of these improvements, diagnostic accuracy can also be greatly enhanced if certain steps are taken prior to the CBCT scan. The use of a radiopaque scanning template helps to provide a concrete relationship between the desired tooth position and the underlying bone, allowing for true restoratively driven planning. Through specific case examples, this article demonstrated important concepts of using interactive treatment planning that can increase diagnostic acuity. When it is important to understand the soft tissue biotype, soft tissue thickness, emergence profile, facial or buccal plate thickness, enhanced implant and/or abutment planning, and extent of the labial vestibule, a cotton roll placed within the vestibule prior to the scan acquisition can provide a simple and effective solution.

About the Author

Dr Scott D. Ganz maintains a private practice for prosthodontics, maxillofacial prosthetics, and implant dentistry in Fort Lee, New Jersey, USA. He has served as President of the NJ Section of the American College of Prosthodontists and the Computer Aided Implantology Academy (CAI). He has served as President of the New Jersey Section of the American College of Prosthodontists and of the Computer Aided Implantology Academy.

Dr Ganz delivers presentations worldwide on both the surgical and restorative phases of implant dentistry, and has published extensively on these topics. He is considered one of America’s leading experts in the evolution of computer utilisation and interactive software for diagnostic and treatment planning applications using CT and newer-generation CBCT imaging modalities.

Fig. 8. Placing a cotton roll under the lip, as seen in the cross-sectional slice, brings the lip away from the tooth, root, and alveolus (yellow arrows); and defines the vestibule (red arrow).

Fig. 9a. An implant simulated with an abutment trajectory projecting through the clinical crown (green), perforating into the incisal canal.

Fig. 9b. For a screw-retained crown, the screw-access hole would need to project through the lingual/palatal aspect of the crown, dictating bone grafting to cover the exposed threads.

Fig. 10a. Another clinical case which utilised the ‘lip-lift’ clearly illustrates the advantages of placing a cotton roll in the labial vestibule (yellow arrows). The alveolus curves superiorly to the nasal floor (red arrow), and the soft tissue thickness revealed (pink arrow).

Fig. 10b. The outline of the simulated implant (green) and the yellow outline of the virtual tooth allows further inspection of the implant within the desired receptor site, and the thickness of the soft tissue (pink arrow).

Fig. 11. The ‘lip-lift’ technique helps to define the volume of bone required to fill the defect to achieve optimal results (yellow outline).
The use of existing locators to stabilize a CBCT-software derived surgical guide

Conversion of a mandibular removable to a fixed prosthesis

Author_ Dr Barry Kaplan, USA

Introduction

Dental implants have become one of the most predictable treatment alternatives for patients who are missing teeth. Despite the high success rates, which are well documented, most dental implants are still inserted by a free-hand method of delivery. CT and CBCT and have played an increasingly important role in the diagnosis and treatment planning phase, allowing for increased accuracy, predictability, improved appreciation of adjacent vital structures, and decreased complications. The use of CBCT imaging and interactive treatment planning software allows for the simulation of dental implants and abutments, providing the foundation for the fabrication of surgical guides. Surgical guides derived from CT/CBCT datasets have been classified as tooth-borne, bone-borne, and mucosal-borne, and can be fabricated from a variety of methods, including CAD/CAM and stereolithography or 3-D printing of resin material with the incorporation of metal guide tubes.

Stereolithographic guides derived from CBCT data and interactive treatment planning software allow for precise placement of implants around vital structures and reduced alveolar support and control for depth, angulation and position. While most guides have been either supported by teeth, mucosa or bone, other guides have gained support/stability from mini implants. The 2014 Consensus paper (IJO MI) reviewed the literature regarding the accuracy of guided surgery for implant placement. The Consensus paper found that bone-supported templates had greater deviations than mucosal or mini implant-supported guides and tooth-supported guides were the most accurate. With regard to accuracy, clinical deviations at the point of drill entry have been reported from less than 1 mm to 1.5 mm. Errors at the apex have been reported to be from 1.5 mm to 3 mm (more dependent on implant length) and angulation errors were reported from 5 degrees to 8 degrees. With these errors in mind, it would be prudent to plan a safety zone of at least 2 mm from adjacent vital anatomical struc-
tures to obviate injury. Ideally, increased stability of the template, and the placement of the guide tube closer to the top of the implant, should result in a higher degree of accuracy.

When evaluating potential dental implant receptor sites in the anterior maxilla, posterior maxilla, anterior mandible, or posterior mandible, it is imperative that the information derived from the CT/CBCT scan be properly evaluated in all views afforded by the software. Implant placement in the posterior mandible can offer unique challenges. These include lingual undercuts, proximity to the mandibular canal, quality of bone, reduced alveolar support, and limitations of interarch space. Recently, differences in the morphology of the posterior mandible have been elucidated. The mandibular premolar areas have more caudal divergence than the molar areas, which tend to be more parallel. Greatest variations in buccal and lingual width seem to vary most at 4 mm apical to the bony crest. Moreover, males tend to have wider ridges than females, whereas age did not seem to be a significant factor.

_Case report_

A 75-year-old female patient presented with an existing mandibular complete overdenture, supported by three mandibular implants (Straumann) with Locator abutments (Zest, Zest Anchors) (Fig. 1). It was the patient’s desire to have a fixed restoration if possible. After a clinical examination, radiographs, and CBCT scan, it was determined that six additional implants could be placed so that a fixed restoration could be fabricated. Four of them were placed in the posterior mandible and two other in the anterior region. The new implants, located in the posterior mandible, had compromised alveolar bone height and were in close proximity to the mandibular canal. Therefore, the need for additional stabilization of the guide, beyond that derived from the bone support, was paramount. To gain the required stabilization, a plan was developed to use the pre-existing implants with the original Locator abutments as a method of securing a bone-supported template to increase surgical accuracy.

Rathi et al presented a report in which Locator attachments were utilized to stabilize a guide while transitioning a patient from an over-denture to a fixed prosthesis using an ‘All on Four’ protocol. While that article highlights the utility of such a procedure, the current clinical case report underscores the need to ensure the stability of the template when the proposed implant sites are in close proximity to vital structures.

The patient revealed a history of bruxism, which accelerated the loss of retention of the nylon inserts (Locator males), rendering her prosthesis ineffective during function, and required frequent replacement. The need for a completely implant supported fixed restoration became apparent, and the patient was motivated to proceed with the diagnostic phase. The conventional treatment of five implants between the mental foramen to support a fixed-hybrid restoration with a posterior cantilever would not have been acceptable due to the possibility of overloading the implants, given the history of bruxism. Therefore, it was determined that posterior implants were necessary to help distribute the load for a fixed restoration. When implants are placed distal to the mental foramen, the issue of mandibular flexure must be respected, although this affects a very small percentage of patients. To accommodate the clinical presentation and the patient desires, a fixed-type implant-supported

_Figs. 2a–d_ Cross-sectional images of the three existing Straumann implants and the intended abutment projections with superimposed implants: original implant (a); mandibular left first premolar (b); mandibular right central incisor (c); and mandibular left first premolar (d).

_Fig. 3_ Demonstrates a simulated implant within the receptor site with a Locator abutment as selected from the software library of implants and abutments (DENTSPLY Implants) and superimposed on the mandibular 3-D reconstructed volume to aid in the planning process.
prosthesis was treatment planned that would include an interlocking type attachment to break the stress of cross-arch stabilization.

Utilizing state-of-the-art CBCT imaging and interactive treatment planning software, it is now possible to accurately assess the relation of the bone and implant receptor site to the desired tooth position. Therefore, in the digital milieu, thought must first be given to how the proposed position of the teeth (if they are missing) can be incorporated into the scan.

In this case, the patient’s existing dentures were duplicated with a radiopaque material (BarliOpaque Salvin Dental Specialties) to be worn by the patient during the scan acquisition. During the scan acquisition, the patient wears the duplicated prosthesis with the radiopaque teeth. The scan was set at a 0.3 mm voxel size (i-CAT).

The DICOM data can be interpreted with the native software packaged with the CBCT device (Tx Studio, Imaging Sciences International), or it can be exported to a third party 3-D planning software (SimPlant, DENTSPLY Implants) for purposes of using the advanced treatment planning capabilities. When planning ideal implant positions, it is imperative to use 3-D planning software so that the appropriate length and width implant can be placed in the receptor sites. Implants should be placed optimally in the receptor site, away from vital structures, such as the path of the inferior alveolar nerve, and to insure that there is a sufficient volume of bone (Triangle of Bone) surrounding the implant and that the implant position is consistent with the restorative plan.6,7 After careful evaluation, favorable bone height and width was identified for four posterior implants and two anterior implants (Fig. 4). Note that each simulated implant also contained an abutment projection (green), which aligned to the desired radiopaque tooth position.
To ensure accurate restoratively driven planning, the laboratory fabricated denture wax-up was scanned with a desktop optical scanner and then, using advanced software tools, the resulting STL file (standard triangulation language) was subsequently superimposed on the 3-D volumetric reconstruction, and validated in all views using the radiopaque teeth and existing locator abutments as fiducial markers (Fig. 5). In this way, the trajectories of the virtually planned implants could be sighted through the envelope of the denture teeth (the restorative space). Using the information from the 3-D planning, the holes to receive the temporary abutments could be predrilled in the interim fixed prosthesis.

Once the implant positioning was confirmed in the 3-D plan, a CBCT-derived surgical guide was printed in resin by the rapid prototyping process (stereolithography) from an STL file (Fig. 6). This guide essentially carries the 3-D plan to the mouth by virtue of tubes in the guide that will guide the drills to the same trajectory as the planned implant. Additionally, a biomedical model of the mandible was printed to further enhance the pre-surgical planning process (Figs. 7 & 8).

The virtually planned posterior implants were in closer proximity to the mandibular nerve than the ideal safety zone of 2 mm; therefore, it was decided that enhanced stability of the surgical guide could be achieved by connecting the stereolithographic guide to the middle locator abutment with a locator housing embedded in the resin. The increased stability of the guide would thereby improve drilling accuracy.

Prior to surgical intervention, a piece of rubber dam material was sized to the printed biomedical model of the mandible to fit around the Locator abutments to be used during the surgical intervention (Fig. 9). The rubber dam serves to help protect the bone from the potential cytotoxic effects of the methacrylate monomer used to capture the locator housing.

_Surgical intervention_

At the time of surgery, the patient was anesthetised and IV sedation was administered. A slightly lingual crestal incision was made starting just anterior to the retromolar pad to the same location on the contralateral side.

A full thickness flap was then elevated to expose the underlying bone and the three pre-existing implants (Fig. 10). The fit of the bone-borne guide was first verified, ensuring that the flaps did not interfere with complete seating of the guide and that the guide was stable on the bone. Once this was achieved, the area corresponding to the Locator abutments on the surgical guide was reamed out to facilitate proper seating of the guide. A Locator (female) housing with the black nylon processing male insert was seated on the Locator abutment intraorally. The guide was rechecked for proper circumferential clearance and subsequently picked up with a dual-cure acrylic (Chairside, Zest Anchors) and the rubber dam material was subsequently removed (Fig. 11).
The planned six osteotomies were completed with the surgical template with embedded guide tubes, and the universal drill key system, which allowed for precise drilling of each osteotomy (Universal Drill Kit, SimPlant, DENTSPLY Implants). Four osteotomies were positioned in the posterior mandible and two osteotomies were positioned in the anterior mandible. Each osteotomy was purposely undersized to insure good stabilization of the implants (Touareg Adin Dental Implant Systems). After the template was removed, each implant was hand-torqued into position, and ISQ values (Implant Stability Quotient) were obtained (Osstell). Each implant ISQ value was measured to be 68 ISQ or higher, values consistent with immediate restoration.6,10 All the posterior implants were 5.0 mm in diameter x 6.3 mm in length, except for the implant in the lower left first molar area, which was 4.2 mm in diameter x 6.3 mm in length. The two anterior implants located in the mandibular right lateral area were 4.2 mm in diameter x 16 mm length, and the mandibular right second bicuspid area was 4.2 mm in diameter x 13 mm in length (Fig. 12).

Once the new implants were delivered, the Locator abutments were removed from the three original pre-existing implants, and were substituted with multi-unit screw-receiving abutments which received temporary titanium cylinders (Adin Dental Implant Systems). Additionally, the two anterior implants that were just placed also received multi-unit abutments and cylinders for a total of five implants, which were to be loaded. The posterior implants received cover screws and were buried under the soft tissue after the flaps were repositioned and primarily closed with sutures.

A fully extended acrylic denture was first positioned over the implants, and the posterior intaglio surfaces were hollowed to facilitate proper seating of the denture over the posterior cover screws. The purpose of the pink denture base was to help stabilize the denture while it was being connected to the temporary titanium cylinders. Once the connections were achieved, the pink denture base areas were removed with an acrylic laboratory bur, and the flange area contoured to serve as a fixed implant-supported screw-retained provisional.

**Conclusion**

The process of guided surgical applications for dental implants continues to be refined and improved as the software technology and hardware components evolve. The use of CBCT and interactive treatment planning software have significantly impacted upon the diagnostic capabilities which aid clinicians in accurately assessing individual patient anatomy, providing increased accuracy to determine proper implant receptor sites, locating vital adjacent anatomy, and reducing potential complications. CT/CBCT-derived surgical guides play an important role in taking the virtual plan to the surgical intervention. Regardless of the surgical guide type (mucosal, tooth borne, or bone borne), it is imperative that the template does not move to ensure accuracy of the drilling protocol. Stability can be achieved in various ways, including the placement of pins through the host bone, usually required for mucosal templates,
and sometimes for bone-borne templates. Additionally, due to the anatomical restrictions in the mandibular posterior area (i.e. diminished alveolar ridge, vital structures), it is imperative that the computer-aided surgical guide be as stable as possible to ensure accurate drilling, and to avoid potential complications.

The present case report demonstrated how the use of pre-existing implants can be used to aid in the planning phase, and for intraoral fixation and stabilization of the CT/CBCT-derived surgical template. It was helpful that the pre-existing implants had Locator abutments, originally used to stabilize an overdenture prosthesis. Using interactive treatment planning software, receptor sites were determined for the placement of six additional virtual implants to be combined with the original implants to support a new fixed-detachable immediate transitional restoration. The ability to assess both the position of the original implants, and the new implant receptor sites in harmony with the restoratively-driven placement was important to achieve a successful outcome. The enhanced capabilities of 3-D imaging and interactive treatment planning software were combined with the fabrication of a 3-D printed biomedical model of the mandible to facilitate the utilization of the original Locator abutments to improve the stabilization of a bone-supported surgical guide. The clinical protocol insured predictable and accurate results, while helping to reduce patient morbidity. The technique demonstrated in this case report may be applicable to other case presentations when there is an opportunity to utilize pre-existing implants as a method to achieve increased template stability.

References

Restorative-driven implant therapy

Author: Dr Curtis Jansen, USA

Digital dentistry has changed the way I practice— for the better. I'm a prosthodontist practicing out of Monterey, Calif. I've got a progressive and successful practice, with a great team assisting me in providing patients with excellence in dentistry every step of the way. I've had the E4D Dentist and NEVO systems (now Planmeca PlanScan) for more than three years now, and they have provided my patients with a unique dental experience every time I've used them—digital impressions, restorations in one appointment and quicker turnarounds with larger cases. All without compromise in form, fit, function or esthetics.

I've involved my whole team, from Irma, my chairside assistant who has become a CAD/CAM dental designer (CDD) and a clinical integration specialist (CIS), to Frank, a dental technician with more than 30 years bench experience who is now “gaga” over what he can do with a mouse rather than a hot waxing instrument. I do it all—inlays, onlays, crowns and veneers from single tooth to extensive cases.

Take my word for it—if you haven't looked at this type of system in the last couple of years, you haven't looked at all. And don't believe what you've heard or seen before. This technology works.

But now it's gotten even better and in a way that is more passionate to my interests in dentistry—implants. More specifically, it provides all dental professionals a more predictable way to communicate with patients, specialists and laboratories. It's a way to get exactly what you've planned for—restorative-driven implant therapy—with Planmeca PlanScan and Romexis.

In the implant world, we've always talked a good game and have extensive preoperative plans with the laboratory, the surgeon and the patient. We mock up diagnostic plans, get surgical stents and then hope for the best as we send our patient along the implant placement trail.

But, and we've all had it happen, something goes awry. The surgical stent doesn’t make it into the placement procedure or the surgeon puts the implant “where the bone is” and not necessarily where the restoration needs to be. Then what?

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I’ve been lucky enough to be involved and see the development of this exciting software program. It makes everyone’s “wish list” come true. I can draw the nerve(s), view the data from any angle, design the restoration that is right for the edentulous area and then choose one of a myriad of implants to place into the space using just a click and drag of a mouse. Nothing is this easy in dentistry.

Then I can line up the implant with the ideal restorative placement and check the density of the bone and even the angulation of a proposed abutment. Incredible!

This flexibility also allows for efficient and effective communication between the surgeon, the restorative dentist and the laboratory, if needed.

So what’s your next step?

First, if you are a restorative dentist, get Planmeca PlanScan system with Romexis into your office. There is no powder, it’s easy to use, and it makes any office more profitable by being able to complete same-day dentistry and fabricate nearly all your single-unit restorations.

Get going with that system and start scoping out the myriad of excellent cone beam systems listed above or locate a scanning center using one of those brands. Why be tied into just one option? And, more importantly, why be tied into a closed system of the same manufacturer’s CAD/CAM system and cone beam system?

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The more you grasp technology and use its capabilities to guide you to the ideal, the more efficient and effective you will become. So here is your future dialogue with patients missing a tooth who come to see you for restorative therapy. (Note: Patients don’t come to you with the request for “an implant,” they come to...
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“OK, so here is the 3-D virtual model. We can get a better idea of what the ideal restorative solution would be. The computer will assist us in previewing what would be the best functional and maintainable solution for your individual case. Here is the ideal proposal, which we can optimize for your individual situation prior to doing any treatment.”

“It looks like one solution we should consider is a single-tooth implant that would hold the restoration in place and also provide you the most natural feeling and natural-looking solution possible. But first we’ll need to look under your tissue to see if an implant is possible in that location.”

Take Mrs. Smith over to the Planmeca Promax (or any other compatible cone beam system) and complete a cone beam scan. Or if you’ve taken one before on any of the compatible systems, just grab the DICOM data.

“So now we can see the bone available below your tissue. I’m going to combine this data right on this screen and show you what is possible. Here is the implant solution I would recommend, and you can see I’ll place this directly under the restoration we’ve designed and see if you have the type and amount of bone ideal for this procedure.

“We’ll identify the location of the nerve that runs down your lower jaw and certainly avoid that. With this software, you and I can get a great view of the overall process before any treatment is started. So, yes, it looks like this would be an ideal treatment.”

“If we decide to go with this, I have all the information I need. I can be ready when you are, and in fact, I can prepare a temporary restoration and have it ready to place in that space the same day the implant is placed so you’ll never feel that open space again. Your tissues will be able to heal in the ideal form, so when you’re ready, the final restoration will be that much more natural and beautiful. Let’s get started.”

Planmeca Romexis will guide you in the right direction. Share your passion.

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About the author

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Comprehensive solutions for all phases of implant dentistry
In dental implantology, the optimal and truly passive fit of the framework is essential for the long-term success of a restoration owing to the physiology of bone tissue around implants. For a multiple-unit implant-supported restoration, the traditional pouring technique is rather complex and challenging. The difficulty of achieving a passive fit is directly correlated to the number of components used and the volume of the framework. CAD/CAM technology provides such a high level of accuracy that it has revolutionised the field of restorative dentistry.

Today, many implant manufacturers collaborate with industrial companies to develop state-of-the-art machining solutions for their implant-supported frameworks. In that regard, the concept developed by Simeda (Anthogyr) is innovative and supported by many years of proven success in the fabrication of CAD/CAM dental restorations. The major advantage of CAD/CAM technology is that it guarantees a highly accurate and predictable fit (< 10 µ). This clinical case report demonstrates the high potential of this novel digital solution.
Patient presentation

The male patient was a former smoker and 51 years old when the treatment was initiated. He presented with high blood pressure and took Tahor (Pfizer) on a daily basis. In addition, he had been on Kardegic (Sanofi) therapy since a heart attack in 2005. For functional and aesthetic reasons, he wanted a fixed prosthesis in his maxillary arch (Figs. 1a & b).

Debridement and pre-implant surgery

Owing to the periodontal condition of his remaining maxillary teeth, all of them were atraumatically removed. Then, mechanical debridement was performed through alveolar curettage and copious irrigation with Betadine. A maxillary complete overdenture was fabricated and placed on the same day of the extractions.

After a healing period of four months, DentaScan images (GE Healthcare) were obtained to evaluate the bone height. The scans showed significant bone resorption in the posterior sections of the maxillae (Figs. 2a–c): SA–4, according to Misch’s classification, since the residual ridge height was less than 5 mm. Sinus grafting was deemed necessary and implant placement had to be delayed by five to six months, until complete healing and good initial stability had been achieved.

Bilateral sinus lift was performed under local anaesthesia from a lateral approach using the technique described by Tatum. The Schneiderian membrane was lifted gently. As there were no perforations, platelet-rich fibrin was used for coverage of the sinus floor. Maxgraft (botiss biomaterials) allografts were placed to elevate the maxillary sinus floor, and then covered with a Bio-Gide (Geistlich) collagen membrane and platelet-rich fibrin.

After a healing period of five months, the patient underwent a CT scan wearing a scan prosthesis of acrylic resin and commercially available teeth for visibility of the desired tooth location in the CT images (Fig. 3). The CT examination showed adequate bone volume in the grafted posterior regions and an even sinus floor with homogeneous allografted areas. The dome-like shape of the vestibulo-lingual cross-sections was indicative of the absence of material leakage into the maxillary sinuses (Fig. 5a).

Fig. 3 Scan prosthesis.
Fig. 4 An osteotensor.
Fig. 5a Implant placement planning in SIMPLANT (DENTSPLY Implants) software.
Fig. 5b Implant placement planning in SIMPLANT (DENTSPLY Implants) software.
Figs. 5c, d CT cross-sections.
Fig. 6 Axiom PX implant (Anthoogy).
Osteogenic activation

I performed osteogenic activation of the processed maxgraft bone used for sinus lift using the technique described by Scortecci. A trans-parietal approach was used for insertion of the Bone Matrix Osteotensor (Victory) after a minimally invasive flap-less protocol (Fig. 4).

Endosteal stimulation results in osteogenic activation and allows evaluation of the mechanical strength of the grafted areas by probing. Owing to this simple and minimally invasive technique, the initial quality of the future recipient bone site is easily assessed. These techniques have been successfully used in orthopaedics for ten years. In view of the excellent response to osteogenic activation, it was decided that implants would be placed 45 days later.

Treatment planning

The case was planned in the SIMPLANT (DENTSPLY Implants) treatment planning software. The scan prosthesis is critical for determination of the correct position and axial alignment of the implants; visualisation of the emergence profile; and determination of the size, position and axial alignment of the abutments. Furthermore, it allows optimal use of the available bone height. At this stage, special attention should be paid to 3-D positioning of the implants and particularly to the emergence profile in order to facilitate the fabrication process of the final restoration. Straight or angled conical abutments are now clearly visible on the vestibulo-lingual cross-sections. Ten Axiom PX implants (Anthogy) were planned for a maxillary screw-retained bridge restoration (Figs. 5a–c).

Implant placement

Implant placement was performed under local anaesthesia using the case-specific surgical guide. For this patient, I used a specific implant design (Axiom PX, Anthogy) with symmetrical double-lead threads (self-drilling and self-tapping) and a reverse conical neck (Fig. 6). Its unique design, combined with a special drilling protocol, promotes bone condensation even in soft bone, ensuring excellent initial fixation. The BCP (biphasic calcium phosphate) sandblasting technique yields an implant surface with superior osteoconductive properties that positively influence the development of osteoblastic cells in the early stage of osseointegration. A flapless technique was used for implant placement. The flapless technique has definite advantages: preservation of the subperiosteal blood vessels, and improved patient comfort owing to a shorter operating time and simple post-operative care.
case report  _full-arch restoration_

It was agreed with the patient that the implants would be immediately loaded, provided that good initial stability was obtained. The temporary removable prosthesis would be worn for a limited period. Fortunately, adequate stability was achieved, allowing for immediate loading. Each implant (except #27) was torqued to 35 Ncm or more. On the same day, an impression was made using the pick-up technique, with a previously prepared impression tray. First, the final straight conical abutments were hand tightened into the implants using a torque of 15 Ncm. They were intended to accommodate the screw-retained provisional and then the final screw-retained prosthesis.

The Axiom PX implant system offers two major advantages: platform switching and indexing trilobe Morse taper connection. The latter greatly facilitates abutment placement. A tight stable connection guarantees integrity of the soft tissue (Fig. 8).

In the laboratory, the master model with the embedded analogue was used to fabricate a master plaster cast. A high-rigidity cobalt-chromium and resin temporary bridge was fabricated, tried in, and transferred to the patient's mouth 48 hours after the implants had been placed. This provisional device would serve as an external fixator during osseointegration of the implants.

A control radiograph was taken to confirm the passive fit of the framework. The temporary bridge was hand tightened to a torque of 10 Ncm. The occlusion was accurately adjusted (Figs. 7a–c). The patient wore the temporary bridge for six months. During that period, a number of parameters were evaluated, including occlusion, osseointegration status, oral hygiene, mastication, phonetics, aesthetics and lip support. The temporary bridge should be rigid (framework) and easily removable (screw fixation). Site #27 healed uneventfully, protected as it was from mechanical stress.
At the end of the six-month healing period, preparation for the final restoration began. Wearing the temporary bridge had allowed adjustment of the above-mentioned parameters (e.g. aesthetics, phonetics and lip support) and validation of the vertical dimension and intermaxillary relationship.

The temporary bridge was removed, an implant stability percussion test was performed, and control radiographs were taken. The straight conical abutments that had been placed concomitantly with the implants were tightened to 25 Ncm (as recommended by the manufacturer), except abutment #23, which was angled (Fig. 8).

An impression of the final bridge was taken with the same impression tray used for the temporary bridge. Pick-up transfer copings were interconnected using LuxaBite resin (DMG), and the impression was made using Impregum (3M ESPE). The master model, including the conical abutment analogues and silicone soft tissue (representing the patient’s gingiva), was fabricated and then validated in the dentist’s office via a wax bite block (into which extra-hard plaster material was poured). The wax bite block was then tried in (Figs. 9a–d).

Using silicone indices (vestibular, occlusal and palatal) from the temporary bridge, a wax-up was fabricated in the laboratory (Fig. 10). The wax-up had to meet the aesthetic demands of the patient and be an exact replica of the temporary bridge (both anatomically and aesthetically). The validated master model and wax-up were sent to the SIMEDA machining centre, where the master model was scanned and a CAD model was designed (Figs. 11a–d). A PDF 3-D file is used to validate the design, after which the manufacturing process can be initiated. All pieces are machined from titanium blocks using high-precision five-axis milling machines (Figs. 12a–c).

Titanium is a lightweight material and, more importantly, it is highly biocompatible and has superior mechanical properties. It is four times lighter than commonly used semi-precious alloys. Actually, it is the lightest metal used in dentistry. Furthermore, titanium is a self-passivating metal: it readily reacts with oxygen in air to form a tough layer of oxide, which protects against corrosion. Titanium is known to resist corrosion and chemical attacks extremely well. Furthermore, it is bactericidal, a key advantage for dental implants. Material density is a crucial factor in implantology. We believe that the weight of a maxillary implant-supported prosthesis is the most important factor for the outcome of the restoration.
A few days later, we received the framework for try-in. It had a perfect passive fit and was returned to the laboratory for veneering. The metal preparation in the laboratory entailed sandblasting, titanium etching, and the application of opaque porcelain to conceal the metal core. The bisque-baked restoration was then tried in to allow the patient to validate the aesthetics of the restoration. This step is necessary to assess static and dynamic occlusion and perform minor adjustments (Figs. 13a–g). The bisque-baked restoration was then returned to the laboratory for fine tuning and glazing.

**_CAD/CAM benefits_**

Although conventional casting techniques have evolved, they are still fraught with inaccuracies owing to the nature of the materials and to their handling. This includes the risk of errors during investment processing, risk of metal deformation and poor metal homogeneity. The CAD/CAM technologies used for producing metal frameworks are essential to the quality of the final restoration (Fig. 13i). The CT scan data is converted into a format that allows the 3-D images to be utilised by the selected treatment planning software. The case is then planned in the software.

The CAD software has databases that allow the creation of virtual models for the desired restoration using different materials, including zirconia, titanium, cobalt–chromium, IPS e-max and PMMA.

If the dental laboratory has its own scanner, an STL file is sent directly to the production centre by e-mail. Otherwise, both the model and the wax-up are forwarded to the production centre by courier.

If the computer settings are correct, one is ensured of perfect reproducibility in the manufacturing process and consistency in the result (i.e. a truly passive framework fit). Optimal setting of the coping thickness parameter or the pontic connection parameter may prevent torsion or deformation of the framework during firing of the ceramic. Subtractive manufacturing, combined with digital modelling, eliminates the risk of alteration of the material structure. The resulting metal framework will have optimal homogeneity and density.

As regards fabrication of implant superstructures, machining is the technique of choice for achieving high precision and near passive fit. Practitioners can expect consistent and reproducible results, excellent framework fit, and regular, accurate prosthetic seals.

**Conclusion**

Today, dental laboratories are using high-tech scanning equipment, which allows digitisation of the master model (to determine the implant index) and the wax-up. CAD/CAM offers a level of quality and accuracy unsurpassed by any of the traditional techniques. Passive fit, which is critical to the outcome of an implant-supported prosthesis, is a determinant of the long-term success of a restoration. Passive fit of the framework for a long-span restoration is much easier to achieve and reproduce with CAD/CAM than with the traditional pouring techniques.

The use of CAD/CAM machining for implant-supported restorations guarantees a highly accurate and predictable framework fit (< 10 µ). In addition, machining centres can produce restorations using fully biocompatible materials, such as titanium and zirconia. In order to take advantage of the accuracy of CAD/CAM, using safe and reliable implant systems with superior biological and biomechanical characteristics is required.

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Abstract

We report the case of a 17-year-old patient who came into the clinic because she had noticed a colour change to the maxillary left central incisor (tooth #21) of 48-hour duration. During clinical examination, tooth #21 appeared darker than the rest of the teeth. After performing a complete exploration and obtaining no response to vitality tests, a pulp necrosis of tooth #21 was diagnosed.

Differential diagnosis began with the completion of the medical record. The patient had received orthodontic treatment and a supernumerary tooth in the anterior region of the maxilla had been extracted. The patient did not recall having suffered injuries or trauma in the incisal region.

A dental panoramic tomogram was obtained, and a high-density area was observed at the apical level in the area of tooth #21. A 3-D computed tomography (CT) scan was then obtained, and it showed the presence of a supernumerary tooth in the periapical region of tooth #21, palatally located and oriented upwards. Necrosis by compression of the neurovascular pedicle of tooth #21 due to the expansion of the erupting follicle of the supernumerary tooth was diagnosed.

Pulpectomy and surgical removal of the supernumerary tooth were performed. During surgical removal of the supernumerary tooth, the neurovascular pedicle appeared oedematous and congested and was the cause of the tooth pulp necrosis.
Case report

A 17-year-old patient who had undergone orthodontic treatment four years before came into the clinic because she had noticed a colour change to her maxillary left central incisor lasting for 48 hours. The patient presented with a tooth discoloration (Fig. 1) with slight pain that ceased with a non-steroidal anti-inflammatory drug. During the initial visit to her general dentist, vitality tests were performed and a slight response to the tests was detected. After that, the patient was referred to a specialist.

When she presented to the endodontist, the tooth had darkened to a grey-brown colour. In addition to that, the tooth no longer responded to pulp
vitality tests. During the visit, the endodontist performed periapical radiographs of the area (Fig. 2), and based on this the existence of a supernumerary tooth at the apical level of the incisor growing towards the floor of the nasal cavity was confirmed. The endodontist requested a CT scan to study the position and assess the possibility of surgical extraction.

The CT scan showed the position of the supernumerary tooth relative to the roots of the adjacent teeth, confirming growth towards the periapical region of tooth #21, that is, a 180-degree deviation from the correct orientation for eruption in the dental arch. Reconstruction in 3-D showed this phenomenon clearly (Figs. 3–6).

Endodontic treatment of tooth #21 was performed, during which the congested pulp was removed and some bleeding was observed. The length of the gutta-percha obturation was deliberately longer than required in order to facilitate surgery (Figs. 7–9).

Surgical treatment was planned and consisted of raising a semilunar flap on the periapical region of tooth #21 and performing a minimum root resection of 2 mm approximately without a bevel, using a size 0.23 round bur with a straight handpiece, to expose the supernumerary tooth’s crown. The crown was sectioned at the coronal middle third and the incisal portion was removed (Fig. 11). A hole was made in what would be the middle and cervical thirds of the supernumerary tooth to force it up (Fig. 12) and make the extraction through the osteotomy created for apicectomy, thereby achieving a complete extraction (Fig. 13) with minimal trauma to bone and the roots of the incisors.

The oedematous pedicle that was compressed by the erupting follicle of the supernumerary tooth and
caused a lack of blood supply to the pulp of the left central incisor can be observed in the image, held by a haemostat (Fig. 14).

Afterwards, preparation for retrograde root filling was performed using a Satelec ultrasonic system and the appropriate handpiece for this surgery. Retrograde root filling was performed with SuperEBA (Bosworth), thereby achieving sealing of the canal at apical level (Figs. 15 & 16). The flap was closed with three silk sutures (Fig. 17), which were removed after seven days.

Supernumerary tooth after extraction can be observed in the picture (Fig. 18).

Two months after the intervention, internal whitening was performed to improve the colour of the incisor. The last two images show the clinical appearance (Fig. 19) and a radiograph (Fig. 20) three years post-treatment.

_Discussion_

CT scans, which have been widely used in endodontic diagnostics for fractures and fissures, for example, and in implantology, are not yet commonly used in surgical planning to obtain diagnostic and anatomical data. The relevant and detailed information that this imaging technique provides, especially regarding the position of supernumerary teeth, is proof that it should form part of the protocol during surgical planning.

The second point of discussion is the pathway used to approach the supernumerary tooth. We could have used a palatal pathway, but the CT scan revealed that the vestibular pathway was less risky, provided greater visibility and better respected the important anatomical structures, such as the adjacent teeth, without injuring them by accident and risking an iatrogenic injury.
Another important point to be observed is the pathophysiological mechanism that resulted in pulp necrosis. We suspected an apical or periapical resorption of tooth #21 because of the expansion of the erupting follicle and secondary osteolysis, which cannot be excluded. In order to eliminate the greatest number of cells involved in the resorptive-destructive process, an apicectomy was performed. Nevertheless, pulp congestion suggested that the most probable pathophysiological mechanism involved was venous stasis of the vascular plexus that enters the incisor, just before apex.

The last point of discussion is when these supernumerary teeth should be removed. If possible, the best time for removal is before any pathology signs appear. This requires consideration of the individual case of each patient, and performing clinical and radiographic follow-up of the case in order to determine the right time.

_Conclusion_

The presence of supernumerary teeth in the permanent dentition has a frequency of between 0.1% and 3.8%. Necrosis of the adjacent teeth is one of the possible complications of this phenomenon; therefore, clinicians must consider the possibility of a supernumerary tooth during diagnosis, especially in patients with pulp necrosis without previous traumatic dental pathology._

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Nowadays, most people will associate forensic dentistry primarily with identification and bite mark analysis. These areas do indeed form the majority of an odontologist’s workload. There are, however, other aspects of the discipline that are just as important but perhaps less well known. These include cranio-facial trauma analysis, age estimation for both living and deceased individuals, dental manifestations of child abuse, dental malpractice investigations, as well as dental insurance fraud.

Forensic odontology is an integral part of the medico-legal process. With this comes a responsibility borne by forensic odontology practitioners for the requisite education, qualifications and ongoing training. Courts and legal institutions now require that we have evidence-based research upon which we can rest our findings and conclusions. In addition to knowledge of the law, we have to have knowledge of human anatomy and its relationship to injury patterns and interpretation. Knowledge of bite mark patterns due to assault, trauma and sexual abuse, as well as child abuse injury manifestations, is also required, as is knowledge of assessment techniques used when the age of an individual is unknown. Finally, there is a need to have knowledge of human identification methods, principles and practices, as well as mass disaster identification procedures and protocols, and the ethical issues involved in the examination and management of dead bodies, and to have an understanding of human rights issues involved in war crimes investigations.

All of these require thorough knowledge of cranio-facial anatomy, dental anatomy, dental and skeletal development, injury interpretation and medico-legal report writing. It is also important to have a good understanding of the law relating to the practice of dentistry, the coronial system, and the criminal justice system. As the majority of the forensic odontology caseload concerns the identification of unknown deceased individuals, most discussion in this article will concentrate on this.

Honouring the dead is a fundamental precept in all societies. The extent of this communal attention to the deceased varies across the world, but in essence every person hopes that his or her remains will be treated with respect after death. This respect for the dead includes, for many societies, robust identification so that relatives and friends are able to treat the remains with appropriate ceremony and are able to visit the resting place of the deceased whenever they wish. So important is the perception of personal identification in almost all societies that authorities will go to extraordinary lengths to ensure that deceased individuals are not interred in unmarked graves, or cremated without a name.

To be buried anonymously goes against all of our religious, cultural and ethical belief systems, and implies that a life unremembered and unmourned was really a life without consequence. William Gladstone, Prime Minister of Britain in the mid-1800s, encapsu-
lated this sentiment better than most when he said, “Show me the manner in which a nation cares for its dead and I will measure with mathematical exactness the tender mercies of its people, their loyalty to high ideals, and their regard for the laws of the land.”

Hal Hallenstein, the Victorian State Coroner from 1986 to 1994, also had firm views concerning the importance of human identification, articulated in the following quotation: “It is a hallmark of our civilisation that we regard it as an affront, an indignity, an abrogation of our responsibilities, that a person could live amongst us, die and be buried without a name.” In fact, the importance of identification of the deceased is enshrined in the Victorian Coroners Act 2008 (Section 67), which states “A coroner investigating a death must find, if possible, the identity of the deceased, the cause of death, and the circumstances in which the death occurred.”

Positive identification of the deceased not only satisfies a commitment to probity, but also resolves many legal issues surrounding an individual’s death, such as inheritance and life insurance. If a deceased person remains unidentified, then technically he or she will not be declared dead for a number of years, thus creating further distress to families who not only are unable to put their lost loved one to rest, but may suffer financially as well.

Personal identification of the deceased, and occasionally the living, is achieved through a variety of scientific and sometimes unscientific methods. Practitioners from forensic science, forensic medicine, law enforcement and coroners’ offices apply their own particular set of skills to an identification problem in order to arrive at an answer. The most common method used to identify the deceased in all jurisdictions is undoubtedly visual recognition by a relative or close friend. There is continual debate concerning the veracity of this method, given the propensity for error, which has been well documented, especially in mass casualty events and in situations in which the deceased has suffered trauma to the face. From the forensic medical/scientific perspective, visual recognition is not proof of identity, but is only presumptive.

Methods used to achieve positive human identification can be separated into two broad categories. The first consists of those methods that are presumptive for identification, such as circumstantial evidence, property associated with the body, and visual recognition. These methods involve a high degree of subjectivity and rely on identifiers that are not intrinsic to the body itself, are dependent on lay interpretation, and therefore can be falsified or mistaken (commonly known as secondary identifiers). The second category relies on scientific analysis of identifiers that are intrinsic to the body, such as dental restorations, fingerprints, DNA, and verifiable medical records (primary identifiers). These involve characteristics that can be objectively appraised and compared to ante-mortem exemplars in both a quantitative and a qualitative way and that are difficult or impossible to falsify.

Of all the scientific methods, molecular biology is the only method that can mathematically quantify the degree of certainty for a particular match, with the other methods (including odontology) being somewhat dependent on more subjective methodology and expert opinion. This reliance on even a small level of subjectivity can raise issues in courts when lay people do not have a deep understanding of the methods employed in an expert’s conclusion.
confusion can arise from the fact that there is often no unanimous indication regarding which and how many characteristics are necessary in order to achieve a positive identification. The recurrence of discordant features excludes identity; the occurrence of several concordant features commonly observed within the population does not allow a final judgment on identification, whereas even a few features rarely observed can lead to a positive match. An example of this is a case in which the written dental chart describes amalgam restorations in each first molar. If the same is found in the deceased, is this sufficient evidence to confirm identity? Definitely not, as many people share this restoration pattern. If, however, we also have ante-mortem radiographs of those restorations displaying the exact shape, size and location within each tooth, and these compare favourably with the post-mortem radiographs, then few would argue that a positive match cannot be confirmed. There is, however, still no way to quantify this match, to put a probability ratio or a percentage certainty to it.

It may be necessary in some cases to compare all of the teeth in a mouth in order to arrive at a match. In other cases, a single tooth with an unusual or complex restoration may be sufficient. It has long been the wish of identification experts to be able to quantify such matches, but no reliable method has yet been devised and so a degree of expert subjectivity is still required.

Prior to the availability of scientific methods applicable to the issue of positive human identification, the only real option for relatives and friends to recover the mortal remains of their loved ones was to visually examine them, and make a decision regarding whether the person before them was indeed who they believed him or her to be. On the face of it, positive human identification by visual recognition would seem to be a fairly simple matter, as long as the deceased has undamaged facial features. We can all recognise people who are well known to us by their facial features and mannerisms, even in poor light and at odd angulations. This has been shown to be true in many studies concerning the recognition of living people via CCTV security footage. Why then are there documented cases of misidentification through visual recognition of the deceased, even of intact and undamaged faces?

The process of visual recognition is complex and until quite recently not well understood. Clues as to the identity of an individual, either living or deceased, rest not only with the physical structure of the face, but also with the variety of facial expressions, the display of various mannerisms, and the context in which the individual is seen.

A deceased person has lost all facial expression, animation, and context and simply looks different from when he or she was alive. Incipient decomposition changes may also be present and go unrecognised. Couple this with the stress and trauma being experienced by the identifier, who may well have never seen a dead body before, and it is easy to see how someone may make a mistake. This is compounded by the way visual identifications are often performed, in that the deceased is presented to the identifier to confirm what the authorities already believe they know.

Identification methods

Visual recognition, despite the lack of scientific validity and the propensity for error, will for all practical purposes remain as a major method for positive human identification. When it is determined that visual recognition is not an option, usually because of trauma, incineration, decomposition, or multiple deaths resulting from a single incident, then forensic practitioners are able to rely on more scientific means to determine identity. The common methods employed include molecular biology, medical record comparison, fingerprints, and dental record comparison.

DNA profiles are encrypted sets of numbers that reflect a person’s DNA make-up, which can also be used as the person’s identifier. Although 99.9% of
human DNA sequences are the same in every person, enough of the DNA is different to distinguish one individual from another, unless they are monozygotic twins. DNA profiling uses repetitive sequences that are highly variable, called variable number tandem repeats (VNTRs), particularly short tandem repeats. VNTR loci are very similar in closely related humans, but so variable that unrelated individuals are extremely unlikely to have the same VNTRs. In situations in which a full nuclear DNA profile is not attainable, for example in ancient or degraded remains, mitochondrial DNA analysis may be used, although with less certainty. Identification using DNA evidence relies on the comparison of an ante-mortem sample (reference sample) with a post-mortem sample, and may include direct comparison of the decedent’s DNA (e.g. Guthrie cards or an ante-mortem blood sample), or a comparison with relatives’ DNA (parents, children or siblings), to arrive at a conclusion. The conclusions of molecular biologists are expressed as a probability ratio and are thus scientifically quantifiable as to the strength of the match. With any DNA technique, the cautious juror should not convict on genetic fingerprint evidence alone if other factors raise doubt. Contamination with other evidence (secondary transfer) is a key source of incorrect DNA profiles, and raising doubts as to whether a sample has been adulterated is a favourite defence technique.

Identification using fingerprints (friction ridges) relies on an examination of ante-mortem prints already on file with authorities (exemplars), or more commonly comparison with latent prints retrieved from an object the subject of the examination was known to have touched. Fingerprint identification involves an expert, or an expert computer system operating under threshold scoring rules, determining whether two friction ridge impressions are likely to have originated from the same finger or palm (or toe or sole). The validity of forensic fingerprint evidence has been challenged by academics, judges and the media. While fingerprint identification was an improvement on earlier anthropometric systems, the subjective nature of matching (especially when incomplete latent prints are used), despite a very low error rate, has introduced an element of controversy.

Medical record comparison can be used for identification purposes when there is sufficient ante-mortem evidence of unique medical intervention or disease. Examples include the discovery of medical prostheses, such as pacemakers and prosthetic hips, which will have engraved on them serial numbers, which can then be reconciled with ante-mortem surgical notes.

_Dental identification_

When good quality ante-mortem dental records are available for comparison with post-mortem examination findings, positive identification is a relatively simple matter (Figs. 1a & b). For many cases, however, such a simple resolution is not so easily achieved. Often ante-mortem dental records are incomplete or many years old or there are no radiographs. Couple this with incomplete remains or remains damaged by fire and/or trauma and the difficulties are magnified (Figs. 2a–c). Reproducing the exact angulation and aspect of an ante-mortem radiograph in a post-mortem radiograph, taken in less than ideal circumstances, can also be challenging. In order to reach conclusions to these difficult identification puzzles, the forensic dentist not only needs a solid grounding in all of the techniques available, but also requires a level of experience and, in the early years, a degree of mentoring.

Dental identification is not only achieved using comparison of restorations; other features of the teeth and maxillofacial skeleton may also be employed. Root morphology, sinus configuration, unusual crown shape, and pulp chamber morphology are all factors that can be considered in the absence of restorations, as long as there are high-quality ante-mortem images with which to make a comparison. Study models, sport mouth guards, partial dentures, orthodontic appliances and photographs of the dentition are all useful aids for a forensic odontologist and are employed with varying degrees of certainty, depending on the circumstances of the case.
Personal identification via dental record comparison is similar to fingerprint analysis in that there is, as discussed above, an element of subjectivity involved in the matching process. Where dental identification differs, and is perhaps easier to comprehend for lay people, is in the nature of the evidence being compared. With dental evidence, matches are commonly assessed by comparing both ante-mortem and post-mortem radiographs of easily identifiable man-made (and most often handmade) restorations. Unlike the minute nature of the whorls and swirls of fingerprint evidence, dental radiograph comparisons are often so obviously similar that any reasonable person is able to say that the images belong to the same person.

Aside from identification case work, odontologists are asked to provide medico-legal opinions on a variety of topics as outlined in the introduction. Bite mark interpretation is probably the most recognisable of these to the lay audience and involves the assessment of injuries to the skin that are suspected of being caused by human teeth. This area of forensic practice is fraught with difficulty, as the highly subjective nature of the conclusions reached is almost completely based upon opinion rather than scientific research. There are so many problems associated with the interpretation of bite marks that to describe them all here is beyond the scope of this introductory article.

Age estimation has always been a function of the forensic odontologist, and traditionally has been based upon interpretation of dental development and comparison with published standards for tooth development (Fig. 4). The majority of age estimation work has concentrated on the ageing of children up to 15 years. Beyond this age, dental development becomes relatively unreliable, as only the third molar is available for assessment, and this tooth is notoriously variable in its development. It has been recognised recently, however, that published standards for tooth development may not be as accurate as assumed, owing to the fact that they were constructed many decades ago and in other parts of the world, and therefore may bear little resemblance to modern populations. Considerable work is currently underway to address this issue, with new population datasets being established around the world.

Odontologists are also researching the ability to estimate more accurately the age of older individuals, around the adult/child demarcation age of 18 years. This is being achieved through the use of multifactorial approaches, where the third molar and various other skeletal development sites are assessed together in order to arrive at an estimate (Figs. 5a–c). This is seen as important research in light of the increasing need to determine the legal status of individuals such as asylum seekers, accused human traffickers who may be children and risk being incarcerated in an adult prison, child soldiers, and victims of sexual assault in developing countries, all of whom are unlikely to possess proof of age documentation.

It has been shown that more than half of all cases of child abuse involve cranio-facial injuries, perhaps owing in part to the significance of the face and mouth in communication and nutrition. Forensic odontologists are rarely involved in these difficult cases, but despite this play an important role in injury description and providing help with determination of causation. All of the principles involved in cranio-
Facial trauma analysis for adults are applicable here, but with emphasis on the developing anatomy and different biomechanical characteristics of the child facial skeleton.

Dental malpractice and insurance fraud investigations are increasing, partly owing to greater public awareness of what constitutes a dentist’s duty of care and responsibility to patients, and partly owing to our increasingly litigious society. For this aspect of practice, the odontologist requires thorough knowledge of the various pieces of legislation relating to dental practice, the professional codes of conduct, and the latest information on treatment modalities, as well as good medico-legal report writing skills.

Conclusion

Forensic odontology is capable of providing rapid and relatively cost-effective identification of the deceased, as long as reasonable ante-mortem dental records are available. In countries such as Australia, the laws concerning medical record-keeping ensure that dental records are, in the main, of good quality and easily retrieved in the event they are required.

In other countries, this may not be the case, and identification of the deceased in some parts of the world represents a serious and ongoing issue for governments and humanitarian organisations. Good record-keeping is not only of benefit to forensic practitioners, but also relevant to improved health services and outcomes for patients in general, so part of the work of odontologists includes educating health authorities in less developed parts of the world to encourage good record-keeping. The benefit of good record-keeping can be seen in recent mass fatality incidents, such as the Victorian Black Saturday bushfires, where, despite the availability of a well-resourced DNA capability, more than half of all victims were identified by dental record comparison.

The scope of forensic odontology is broader than identification alone and encompasses a range of activities, anything in fact where the practice and theory of dentistry intersect the law. To be a competent practitioner in this discipline requires not only a comprehensive understanding of odontology theory and technique, but also a degree of knowledge and experience in a variety of forensic fields, including law, pathology, clinical forensic medicine, molecular biology and anthropology. The forensic odontologist encounters all of these disciplines in different case scenarios, and in order to understand how the odontologist can contribute best to an investigation he or she needs to comprehend the capabilities and limitations of these fields.

Editorial note: A list of references is available from the publisher.

About the Author

Dr Richard Basset
is a senior forensic odontologist and Head of Human Identification Services at the Victorian Institute of Forensic Medicine in Melbourne in Australia.
3-D imaging: increasing implant accuracy

Implants are making news on a global scale. According to The Wall Street Journal’s Market Watch, the implant market ‘is mainly driven by the rising edentulous population, increasing adoption of advanced dentistry in the developed countries, an increase in disposable incomes and increasing awareness of dental care’.

And while this procedure is growing globally, the report notes ‘The North American market is expected to grow at a higher pace than Europe mainly due to lower penetration and the high adoption rate of advanced dentistry.’ While types of materials and implants are evolving in the market, imaging is key to knowing the precise details of the patient’s dentition that can affect a favorable result. i-CAT FLX has gained a wide reputation for image quality, smooth workflow and low radiation dose.

For planning, i-CAT scans show true anatomy in full 3-D volume and high-resolution individual slices for accurate measurement of bone density and alveolar nerve location. Practitioners can avoid potential surgical complications by checking for root entanglement prior to extractions with automatic nerve canal tracing.

Oval and maxillofacial surgeon, Dr Steven Guttenberg noted that CBCT offers him ‘the data to evaluate potential implant sites, and confidently develop a treatment plan. I can place implants exactly, avoiding anatomical structures, such as the sinuses and nerves, and I can establish precise angles to fit the implant properly in the available bone. With CBCT, my patients’ confidence grows and so does as my confidence to treat them properly and safely.’

In combination with Tx STUDIO software clinicians can combine their 3-D images with intraoral scans for a more complete representation of the anatomy, hard and soft tissues, to increase accuracy of implant placement and restoration design. With these proprietary software planning tools, clinicians can map an entire course of treatment from surgical placement of the implant and abutment, all the way to final restoration. TxSTUDIO 5.3 in conjunction with scans facilitates implant treatment planning of single or multiple implants. The Explorer tool offers a 3-D view with cross-sectional images of a particular point for more detailed visualization of root fractures, sinuses, and pathology. Patients can be more involved in the process with the Video Simulation Tool that can improve understanding and result in greater case acceptance.

To streamline the implant process, an extensive library of implant templates affords best possible selection of suitable implant type, size, location and angulations prior to surgery. To facilitate easy communications with the lab, as well as developing 3-D treatment plans, clinicians can choose to import STL files from either digital models or their intraoral scanner and easily register those with their i-CAT 3-D scan in Tx STUDIO software. This communication with the lab can create the final restorations based on the practitioner’s exact design. Also, i-CAT scan files are universally compatible with all leading surgical guide providers to expand implant planning capabilities.

With all of the implant planning and implementation tools available with i-CAT, an important as-
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pect of the i-CAT brand is the emphasis on control over radiation dose. The i-CAT FLX offers step-by-step guidance for selecting the appropriate scan for each patient at the lowest acceptable radiation dose, as well as full dentition 3-D imaging at a dose comparable to a 2-D panoramic X-ray with QuickScan+. Dr Randolph Resnik said that the lowered radiation is a valuable aspect of the i-CAT system. He notes: ‘The i-CAT scanners produce unparalleled images which are so crucial in the treatment planning for dental implants. Additionally, the flexibility of these units allows the clinician to collimate and select various fields-of-view, thus drastically reducing the radiation exposure to the patient.’

Having experienced the inherent differences in 2-D and 3-D planning, Dr John Russo, concludes, ‘3-D imaging provides safety for my patients and confidence that I am formulating a good diagnosis before developing a surgical treatment plan.’ In the Internet age, where more patients can learn about implants as a treatment option, 3-D imaging can help to guide clinicians from plan to scan to treat increasing surgical predictability and facilitating precise implant placement – with low radiation dose. Cone beam 3-D imaging continues to revolutionize 3-D dental and maxillofacial radiography.

References


All MCENTER products and services, from the initial plan to temporary restoration, are available in one location. MSOFT, MGUIDE and MLAB systems provide doctors with optimum support for quicker, more accurate surgical procedures resulting in better esthetics, predictable outcomes and reduced chair-time. Learn more at: www.mis-implants.com
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_Units in the Planmeca ProMax 3D family offer the unique Planmeca Ultra Low Dose imaging protocol, which enables CBCT imaging with an even lower patient radiation dose than standard 2-D panoramic imaging. This pioneering imaging protocol is based on intelligent 3-D algorithms developed by Planmeca and yields a vast amount of detailed anatomical information at a very low patient dose._

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The Planmeca Ultra Low Dose imaging protocol lowers the effective patient dose by up to 75%.
The Planmeca Ultra Low Dose protocol has changed 3-D imaging completely

Prof. Dr. Axel Bumann DDS, PhD, orthodontist, oral surgeon, and specialist in oral and maxillofacial radiology at MESANTIS 3D Dental-Radiologicum, the largest network of dental 3-D X-ray digital volume tomography institutions in the field of dentistry Germany, said: 'We at MESANTIS 3D Dental-Radiologicum produce about 7,500 CBCT images per year at eight locations in Germany. Our main concern in X-ray imaging is to reduce the possible radiation dose as much as is reasonably achievable (ALARA principle). Traditional digital 2-D X-rays at an orthodontist's clinic usually have an effective dose ranging between 26–35μSv (ICRP 2007). Conventional CBCT images of the head with modern CBCT equipment show an effective dose ranging between 49 to 90μSv.

The latest imaging protocol with a specific associated algorithm is called the Planmeca Ultra Low Dose protocol. In medical terms, it allows radiologists to adjust imaging parameters individually according to the clinical needs of each case. The mA-values, in particular, can be individually adjusted and reduced for each patient, as it is required according to all international scientific guidelines. Therefore, it is possible to further reduce the effective dose significantly by using the Planmeca Ultra Low Dose protocol. Depending on the field of view, nowadays CBCT equipment with a Planmeca Ultra Low Dose algorithm has an effective dose between 4 to 22 or 10 to 36μSv.

Our patients and referring colleagues are always happy to hear that the effective dose for certain indications is now even lower than in traditional 2-D X-ray imaging. Since last year, we have been able to replace the common CBCT protocols with the Planmeca Ultra Low Dose protocol.

At MESANTIS 3D Dental-Radiologicum in Germany, the Planmeca Ultra Low Dose imaging protocol is used either with a small or large field of view. Using the new protocol, a lot of patients can benefit from improved 3-D diagnostics without being exposed to a higher radiation dose.'

Prof. Dr. Axel Bumann declares that he has not received any financial reward or other benefit for this statement.
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X-Mind trium: I need 3 solutions in 1

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Hebecker explained that the new MCENTER offers expert digital dentistry capabilities in support of the fast-growing MIS customer base in the region by concentrating all MIS digital dentistry products and services (from the initial treatment plan to temporary restoration) in one convenient, well-equipped location.

The MCENTER provides a comprehensive range of services covering three main products: (a) MSOFT, 3-D and 2-D virtual implant planning software for prosthetic-driven planning; (b) MGUIDE, an exclusively designed 3-D printed template and dedicated surgical kit; and (c) MLAB (CAD/CAM), for the fabrication of customized abutments and temporary crowns.

“MCENTER products represent some very exciting and innovative advances in digital dentistry technology exclusive to MIS Implants,” continued Hebecker. “The MGUIDE surgical template or guide is a lightweight, open wire-frame design that allows delivery of irrigation and anaesthesia through the template. Special slots built in to the drill permit irrigation to penetrate even while the drill is fully inserted in the sleeve. Also no drill guidance keys are needed, freeing up dentists’ hands for a quicker and more accurate procedure.”

Hebecker explained additional features of the MCENTER guided surgical system, including the MGUIDE Surgical Kit (patent pending), in which all of the drills can be used as final drills and actually help collect bone during the drilling process. The proprietary MSOFT planning software, which offers a top-down planning approach, assists clinicians in creating the ideal treatment plan according to depth, position and angulation of the desired end-result. All components used in the MCENTER process are precision engineered for use with MIS Implants and prosthetic parts to ensure component compatibility for optimum accuracy, reliability and fit.

“I’m extremely excited to officially open the doors of the new MCENTER Europe facility, and especially proud to be able to offer MIS quality and simplicity in providing our customers, doctors throughout the region, with highly accurate and efficient guided implant placement procedures and CAD/CAM solutions,” concluded Hebecker. To learn more about MIS Implants and the MCENTER, please visit the MIS website.
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