Patients who present with a terminal natural dentition in the maxillary arch offer both surgical and restorative challenges for the clinician. A formal diagnostic protocol is essential to determine viable treatment options and to facilitate the desired aesthetic and functional outcome. This can include impressions for study casts, two-dimensional periapical radiographs or panoramic radiography, medical history and current list of medications, and diagnostic wax-ups.

Traditional concepts have advocated first extracting the remaining teeth in a phased approach with socket bone grafting to allow the ridge proper time to heal prior to placement of implants in strategic positions months later. During the interim, the patient would receive an immediate complete maxillary denture. It had been postulated that by allowing the ridge to heal after tooth extraction a certain percentage of bone resorption will occur, especially under the forces of mastication transmitted from the immediate denture. Ideally, the vertical dimension of occlusion will be maintained, as well as an acceptable aesthetic appearance based on sound prosthodontic conventions. The healing phase usually requires three to six months to allow the underlying bone to mature. If either a fixed
or removable implant-supported restoration is desired, a CBCT scan will help determine ideal receptor sites based upon the volume and quality of the maxillary alveolar bone. Once the implants are placed a subsequent three-to four-month healing phase has been required to allow for osseointegration prior to loading and fabrication of a provisional and then final prosthesis.

Technology has evolved for both clinicians and dental laboratory technicians. The adoption of CBCT and interactive treatment planning software have empowered the implant team with state-of-the-art diagnostic tools and new digital workflows allowing for enhanced treatment alternatives and reduced treatment times for patients presenting with a terminal dentition in the maxillary arch. While there may be teeth presenting with a hopeless prognosis, the use of three-dimensional imaging modalities may reveal enough bone volume and bone quality for implant placement after tooth extraction. If an appropriate number of implants can be placed in strategic positions and found to be stable enough at the time of insertion, the restorative plan can be accelerated. However, rehabilitating the maxilla directly with immediate extractions and an immediately loaded implant reconstruction takes careful collaboration with the dental laboratory and may lead to unpredictable aesthetic outcomes. The goal of this case presentation is to demonstrate that digital dentistry can help in predicting the aesthetic outcome before any surgical procedure is engaged.

Case Presentation

Clinical Assessment

A 46-year-old Caucasian male presented as a referral with a pre-existing failing condition of the maxillary dentition (Fig. 1). The patient complained of dental pain, bleeding gums and loose, mobile teeth. Clinically an oral examination revealed tooth mobility, generalised bone loss in both the maxilla and the mandible, generalised bleeding upon probing, multiple subgingival deposits and a malodor (Fig. 2). There was a diastema between the right and left central incisors and other spaces were evident upon inspection. Medically, he had an ASA 2 with Type 2 diabetes that was controlled with medication.

The patient was evaluated for a surgical and restorative implant-supported solution for the hopeless prognosis of the maxillary arch. To accurately assess the patient’s clinical reality a CBCT scan was obtained. The CBCT analysis revealed multiple alveolar bone deficiencies such as: dehiscence, fenestration, vertical and horizontal bone loss and periapical lesions (Fig. 3).

Final diagnosis

Generalised acute periodontitis in both the maxilla and the mandible. The prognosis for the existing dentition was poor and further planning was necessary to determine the most acceptable course of treatment for either delayed or immediate implant placement and immediate restoration as per the patient’s desires. The referring dentist had also disclosed that the patient had been inconsistent with his dental follow-ups. Therefore, before proceeding with any advanced treatment scenario, the patient’s motivation needed to be assessed since complex treatments necessitate cooperation, time commitment, and compliance from the patient. After reviewing the requirements with the patient, consent was granted and the patient elected to start treatment for his maxillary arch and engaged maintenance treatment for his mandibular arch.

Fig. 6a & b: Presentation of the virtual design to the patient for discussion and acceptance.

Fig. 7: GPS digital face bow transposition on the articulator. Calibration of the 2-D photograph by triangulation.

Fig. 8: Conversion of the GPS accepted proposition by the patient into a wax-up on the original study cast.
Data collection included 2-D photographs, alginate impressions, a large field of view (FOV) CBCT scan (Carestream select 9600, Kodak) and a maximum intensity projection (MIP) bite registration. A smile analysis revealed that in maximal lip retraction position only a portion of his teeth were exposed, and no gingival tissue was present within the smile zone. Hence, it was determined that the transition line of the definitive patient’s prosthesis transition would be under the upper lip. It is therefore critical to understand the existing and desired aesthetic condition to facilitate the diagnostic and treatment planning phase as a predictor of the eventual functional and aesthetic outcome.

When presented with hopeless teeth in the maxilla with the desire for an implant supported restorative solution, the treatment protocol often dictates a complete extraction scenario followed by the placement of an adequate number of root form implants needed to support an immediate provisional bridge. However, the aesthetic outcome of this procedure can be unpredictable due to a lack of appreciation of the soft tissue and the uncertainty of the vertical and anterior-posterior position of the final fixed prosthesis.

Previously it was proposed that a “patient acceptance prosthesis” be used to simulate the desired restorative outcome which has been followed with recent advances in computer simulation, intraoral scanners, and the merging of different datasets. The purpose of this paper is to review two innovative protocols that address the accuracy and predictability of full arch extraction and immediate implant placement for fixed implant-supported restorations.
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Innovation No. 1: Smile evaluation

A 2-D digital photograph was taken with the patient’s maximum smile. The photograph was then loaded into a smile design software (3D Smile Designer, Getursmile; Fig. 4), equipped with a specific tool set utilised to complete an accurate smile assessment followed by digital smile design work-up (Fig. 5). When the smile design was completed, the proposed simulations were presented to the patient for comment and ultimately consent to start treatment to obtain the desired aesthetic outcome (Figs. 6a & b). The true innovation relates to transitioning from the 2-D simulation to the 3-D reality with the capability of mounting to an articulator (Panadent). The principle of triangulation established a relationship between the pre-operative 2-D photograph overlaid onto the articulated stone cast of the maxillary arch (Fig. 7). Once the registration process was confirmed, the next 2-D simulation photograph was laid onto the cast to facilitate a real 3-D wax-up (Fig. 8). The wax-up was designed to replicate the simulation of the proposed image of the patient onto the articulator as an accurate prediction of the tooth position and aesthetic outcome within the frame of the patient’s face. Advanced tools allow the computer application control of the different objects based on their density or opacity referred to by the author as “selective transparency”.

The analogue 3-D wax-up model was then digitised utilising a desktop optical scanner and converted to an STL file (standard triangulation language) allowing for manipulation in various software applications. Once the aesthetic plan was confirmed, potential implant receptor sites for the root form implants could be evaluated from the CBCT dataset as simulated within the interactive treatment planning software (SimPlant, Dentsply Sirona). The ideal position for each implant was then determined (Fig. 9). The integration of 3-D images allows the surgeon, restorative dentist, and the dental laboratory technician to plan the position of the implant in a “reverse-engineering” process to match the implant to the prosthesis, or “restoratively-driven” planning,9 (Figs. 10 & 11a–f). The goal is to achieve a precise and predictable position of the implants and the prosthesis in accordance to the simulation proposal.

Advanced features of segmentation with the merged dataset of the 3-D designed prosthesis simulation was then modified by removing the soft tissue while maintaining the arrangement of the teeth (Figs. 12 & 13). The STL file of the prosthetic design was then exported for CAD/CAM processing of a polymethyl methacrylate (PMMA) prosthesis with incorporated screw-access channels within its structure to accommodate the temporary screw-receiving implant abutments. To partially eliminate the uneven topography of the bone and to achieve the required bone width and volume for the implant recipient sites, bone reduction was necessary (Figs. 14–16). As more sophisticated computer diagnosis and treatment planning was developed for producing surgical guides for implant placement, a bone reduction template originally introduced by Ganz10 could be produced to accurately manage the bone to accept a secondary stereolithographic bone-supported surgical guide to drill osteotomies for each implant as per the planning scenario (Figs. 17 & 18).

Implant timing

Based upon a review of the CBCT scan it could be pre-determined that the patient presented with a soft bone density profile. Therefore, it was decided to review each potential receptor site carefully to position six implants in the maxilla (Nobel Biocare, Tapered Replace Conical Connection) to maximise the immediate load protocol. Over the past 30 years it has been well-documented that the standard surgical and restorative procedure to rehabilitate the edentate maxilla or mandible
with an implant-supported restoration would best be served with four to six implants.\(^{12}\) To avoid vital structures and to avoid the necessity of bone grafting an acceptable treatment protocol involves implants that are tilted posteriorly which also serve to increase the anterior-posterior distance to improve the restorative foundation.\(^{13, 14}\)

After a review of the maxillary anatomy, it was decided to place four of the implants at a posterior tilted angle to avoid bone grafting in the maxillary sinus and the canine area. The osteotomies were positioned with the surgical guide fixated to the maxilla for stability. Each implant was placed and torque values and Resonance Frequency Analysis (RFA) were recorded. Once the implants were fixated to the maxilla, the immediate load protocol requires that the surgeon or restorative clinician match the prosthesis to the implants. To facilitate a screw-retained prosthesis it was determined that screw-receiving multi-unit abutments (MUA) be utilised at the time of implant placement (Nobel Biocare, Fig. 19). Multi-unit abutments can vary in tissue cuff height and angulation. Angulated multi-unit hexed abutments provide an additional challenge to both the surgeon and restorative dentist. The rotational position of the anti-rotational feature (hex) of the implant in the bone needs to match the multi-unit abutment angulation to allow for the emergence of the temporary titanium screw-retained sleeve within the channel provided in the prosthesis. The importance of this step cannot be underestimated as the prosthesis needs to fit passively onto each abutment. This rotational timing can be achieved by the markings on the surgical guide which correlate to the internal hex of the implant.

The fixed-detachable prosthesis was fabricated with open channels that allowed the temporary titanium sleeves on each MUA to project through the prosthesis. The voids between the temporary sleeves and the prosthesis was then filled with a luting material (SmartCem 2, Dentsply Sirona). Care must be taken to position the prosthesis carefully onto the abutments usually accomplished with a previously fabricated silicone bite index to properly manage the occlusion. The empty channels made to accommodate the implant temporary titanium abutment sleeves can allow for vertical displace-
ment of the prosthesis before fixating it to the implant abutments. Potential movement may be minor and may not have any repercussion on the aesthetic outcome. If not well positioned, any vertical movement can affect the occlusion of the prosthesis. Occlusion adjustments will then be required causing increased chair and surgical time that the patient must undergo.

Innovation No. 2

As previously stated, the prosthesis can move vertically on the titanium MUA before being luted to the titanium sleeves. This process could cause a loss of precision while seating the prosthesis and lead to restorative or surgical complications while complicating the occlusion adjustments at the initial delivery. Traditionally, the pairing of the prosthesis is made in a freehand manner. The current innovation was made to bypass this intuitive pairing, to predictably seat the prosthesis as the initial plan and achieve little to no occlusal adjustments. A prototype seating 3-D stereolithographic prosthetic guide was designed and printed, to be inserted between the implants’ occlusal surface and the prosthesis (Fig. 20). The “seating guide” allows for a precise positioning of the prosthesis replicating the laboratory mounting (Fig. 22a). Once the prosthesis is luted to the temporary titanium abutment sleeves, the seating guide is removed and the space occupied by the guide will be filled with the patient’s soft tissue (Fig. 23). After fixating the bridge with a luting cement (SmartCem 2, Densply Sirona) a minimal occlusal adjustment was required (Fig. 24). Occlusion was balanced in static and dynamic movements and recorded with a digital occlusal analysis device (Tekscan).

Discussion tilted implants

Common inquiries about tilted implants are: force load on tilted implants, cantilever length, marginal bone loss and the patient’s preference towards minimally invasive treatment alternatives (avoiding bone grafting procedures). Bevilacqua et al. conducted a study to compare and analyze, via 3-dimensional (3-D) finite element analysis, stresses transmitted to tilted versus vertical implants and the surrounding peri-implant bone in the maxilla. The results demonstrated that tilted distal implants with the consequent reduction of the posterior cantilever length, (regarding implant rehabilitation of an atrophic maxilla) rigidly splinted with a fixed prosthesis, decreased the stress in the peri-implant bone and framework.

Del Fabro et al. completed a comprehensive literature review of 758 articles to compare the crestal bone level change around axially placed vs tilted implants supporting fixed prosthetic reconstructions for the rehabilitation of partially and fully edentulous jaws after at least one year of function. The review demonstrated that the tilting of implants does not induce significant alteration in crestal bone level change as compared to conventional axial placement after one year of function. This trend was maintained for up to five years of function. Malo et al. compared marginal bone loss and implant success after a five-year follow-up between axial and tilted implants inserted for full-arch maxilla rehabilitation.

In a study of 891 patients with 3,564 maxillary implants rehabilitated according to the “All-on-4” treatment concept, the results conveyed that axial and tilted implants showed comparable mean marginal bone losses of 1.14 ± 0.71 and 1.19 ± 0.82 mm respectively. The five-year follow-up concluded that tilted implants behave similarly with regards to marginal bone loss and implant success in comparison to axial implants in full-arch rehabilitation of the maxilla.

Pommer et al. proceeded to perform a MEDLINE search of the literature to evaluate: patient satisfaction, oral health-related quality of life, and patients’ preferences toward minimally invasive treatment options for graft-less rehabilitation of complete edentulism by means of dental implants. Their conclusion was that little evidence on patients’ preferences towards minimally invasive treatment alternatives vs bone augmentation surgery could be iden-
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tified from within-study comparison. Patient satisfaction was generally high with graftless solutions for implant rehabilitation of completely edentulous jaws. Comparative research is still needed to substantiate the positive appeal to potential implant patients and possible reduction of the indications for invasive bone graft surgery.

A literature review for the advantages of tilted implants were described by Asawa et al. Several advantages of tilted implants were listed as follows:

1. Stability even in minimum bone volume: longer implants can be used in minimum bone volume with the advantage of increased bone-to-implant contact and a reduced need for vertical bone augmentation.
2. Good clinical results.
3. Eliminates the need for bone grafting which can be invasive with unpredictable outcomes.
4. Can usually be performed in patients with various systemic conditions which are often contraindications for bone grafting.
5. Angulations allow placement that avoids anatomical structures.
7. Reduction in length of cantilevers without performing bone grafting or sinus lifting.
8. Effective and safe alternative to maxillary sinus floor augmentation procedures and to pneumatized maxillary sinus.
9. Distally tilted implants produced improved force transmission compared to vertical implants.
10. Excellent prognosis in short-medium term, as well as long term.

Considering all these advantages, placement of an angulated implant while avoiding invasive procedures like sinus lift and bone augmentation procedures, is a feasible treatment option.

Conclusion

Several protocols are currently available to immediately provisionalise and then restore an implant-supported dentition in the maxilla. “All-on-4” protocols are well represented in the literature. However, the All-on-4 protocols lack the ability of having a preview of the patient’s outcome before the surgery. Even if a photographic simulation is achieved, the dental laboratory will empirically position the teeth on the cast without any metric relation to the pre-op photographic simulation. The All-on-4 protocol includes a conversion technique to modify a complete denture to a fixed provisional bridge. This technique usually requires a lengthy clinical process with occlusal adjustments. In some cases, the occlusal level can be offset from the natural horizontal line or the mid-line can be different from the aesthetic requirements.

Other immediate protocols that are computer driven, such as nSequence (NDX nSequence) and Guided Smile Chrome (ROE Dental Laboratory) do have a precise seating of the fixed prosthesis but do not have a formal aesthetic pre-determination of the patient’s smile. DSD 3-D Planning (Spain) offers similar services but requires training, many more photographic and video collection, and specific software applications over their internet-based network. The current concept was developed to simplify the process of delivering aesthetic full arch immediate loading protocols.

Clearly these new developments offer crucial advantages since aesthetics are a sensitive part of treatment acceptance. Certain limitations are involved in these
clinical innovations. The first step in the process involves taking a photograph of the patient smile. Care must be taken when this photograph is captured to ensure that it reflects the patient’s maximum smile. If the transition line between the prosthesis is visible in the aesthetic zone, the described approach will not be applicable. As the author has published previously having the transition line in the aesthetic zone can require supplemental treatments such as: Botox lip relocation preparing a removable prosthesis with a vestibular extension that will end under the patient’s maxillary lip, or osteoplasty to reduce the vertical position of the maxilla.

Another potential limitation is the selection of the angulated abutments for tilted implants. When selecting angulated abutments, one must choose computer guided surgery software that includes a library for the original design of these abutments. Otherwise, pairing the prosthesis to the angulated abutments will be at risk if the components differ from the virtual design. Additionally, if the surrounding bone is not sufficiently cleared, the MUAs get lodged against the bone and will not fit and a “bone-profiler” may be required to ensure that the abutment will seat fully on the implant.

Other basic metrics are necessary for an immediate load scenario. Bone density and torque level and resonance frequency analysis (RFA) and implant stability quotient (ISQ) are useful to insure a predictable immediate loading success. In any event, pre-planning a backup scenario is imperative if a surgical complication occurs such as: bone fracture on extraction or implant placement, root tip fracture, or loss of the buccal bone plate. Digital technology is quickly becoming an important and essential attribute to all phases of clinical dentistry. The current innovations certainly have a promising future. Time and attention to details are essential to mastering these emerging technologies.

Digital dentistry, including CBCT imaging, interactive treatment planning software, the increased use of rapid prototyping/3-D printing, and improved CAD/CAM and printed materials can help predict the aesthetic outcome before the surgical procedures involved with an immediate implant rehabilitation of terminal dentition in the maxilla, or, as the author states, “before the scalpel ever touches the patient.” It firmly confirms that the adage, “It’s not the scan, it’s the plan” has more importance than ever.

Editorial note: A list of references is available from the publisher. This article was first published in Oral Health, August 2018, p. 20–39.

contact

Dr Gilbert Tremblay, BSc, DMD, Diplomate of the American Board in Oral Implantology/ID, Diplomate of the International Congress in Oral Implantology, Fellow of the American Academy in Implant Dentistry and Fellow of Pierre Fauchard Academy. He has a private practice in Montreal, Canada, and worked in the private sector on computer surgical guide design. He is President and founder of the Quebec Dental Implantology Institute, member of the exam construction committee for the American Board of Oral Implantology, Past President of the North-East District of the American Academy of Implant Dentistry. He can be reached via e-mail at gilberttremblaydmd@icloud.com.

Dr Scott D. Ganz graduated from Rutgers School of Dental Medicine followed by a three-year specialty programme in prosthetics at MD Anderson Cancer Center in Houston, Texas, USA. He is a Fellow of the Academy of Osseointegration (AO), and Diplomate of the International Congress of Oral Implantologists (ICOI), on staff at Hackensack University Medical Center, on faculty at Rutgers School of Dental Medicine, Past President of both the Computer Aided Implantology Academy, and the NJ Section of the American College of Prosthodontists. He has served as a consultant to the industry for more than 27 years, published over 100 articles in scientific journals, has contributed to 15 textbooks, and continues to lecture worldwide. He can be reached via e-mail at drganz@drganz.com.

Figs. 26a–c: Before and after photographs: before (a), after GPS project (b), final restoration (c).