When a patient presents with a failing dentition, there are several different treatment options available if contemplating a fixed prosthesis supported by dental implants. This could include extraction and bone grafting, allowing the ridge to heal before implants are placed, or extractions and immediate placement of implants with concurrent bone grafting to fill any voids in the remaining bony architecture. These two examples would usually leave the patient with a removable complete denture during the healing phase prior to loading of the implants for either a fixed or removable restoration. A treatment alternative was presented by the authors in CAD/CAM 4/2019 which described the necessary steps for achieving restoratively driven surgical planning for full-arch implant reconstruction where implants are loaded on the day of surgery with a prefabricated fixed provisional restoration.

Immediate loading of dental implants offers many advantages over delayed treatment alternatives, including the following: (a) the surgical phase is generally completed in one visit; (b) the pre-established occlusion can be planned in advance to achieve an immediate functional and aesthetic result; (c) the overall treatment time to definitive restoration is reduced; and (d) the number of patient visits is reduced. As technology continues to evolve, so too do the variations in protocols that have
been developed to enhance the process of delivering both preoperative and postoperative treatment. This current article presents innovations that can improve the workflow essential to improving efficiencies and achieving success with single and dual full-arch implant reconstruction.

Diagnostics and surgery

A 58-year-old male patient presented with a failing dentition. The preoperative intra-oral retracted view illustrated missing, broken, fractured and decayed teeth, plaque and calculus accumulation, as well as severe soft-tissue inflammation (Figs. 1a–c). The patient complained of pain and difficulty chewing and exhibited a reduced vertical dimension of occlusion and hyper-erupted posterior teeth (Figs. 2a & b). The pre-existing intra-oral condition was recorded with impressions and stone casts that were then digitised with a desktop scanner. Additionally, an intra-oral scan (3Shape) recorded the existing occlusion. The patient’s anatomy was fully assessed with 3D imaging technology and interactive treatment planning software. Cone beam computed tomography (Carestream) was essential in order to visualise the periapical pathology exhibited by multiple teeth. Using the digitised casts, the dental laboratory completed a virtual tooth set-up to establish the correct plane of occlusion, function and aesthetics. The virtual occlusion was merged with the original tooth set-up to assist in the diagnostic phase of selecting the appropriate implant receptor sites. The dimensions and volume of the alveolar bone, thickness and opacity of the cortical plates, and overall bone density were important in evaluating each implant receptor site, necessary for initial stability. Cross-sectional images reveal the planned positions of each implant to achieve a screw-retained fixed restoration on seven proposed implants (Figs. 3a & b).

The surgical phase was planned to utilise the full-template guided surgical protocol as described in the first article (CAD/CAM 4/2019) and therefore only summarised here. On the day of surgery, the necessary components included the tooth-borne fixation base with pin guide, anchor pins, bone reduction guide, osteotomy drill guide, carrier guide and transitional full-arch prosthesis, and various 3D-printed models for both maxillary and mandibular arches (Fig. 4; CHROME GuidedSMILE, ROE Dental Laboratory). The fixation base was first secured to the pin guide and then seated on the maxillary teeth so that facial anchor holes could be drilled and anchor pins placed through the guide holes of the fixation base. Fig. 5: The fixation base was first secured to the pin guide and then seated on the maxillary teeth so that facial anchor holes could be drilled and anchor pins placed through the guide holes of the fixation base. Fig. 6: The carrier guide was used to accurately position the transitional prosthesis so that it could be secured to the implant sleeves with dual-polymerising composite material.
guide, and anchor pins were then placed transcortically through the buccal surface of the fixation base (Fig. 5). The teeth were extracted, and the bone was levelled according to the surgical plan (red line on cross-sectional images). Based upon the software plan (Blue Sky Plan), seven implants were placed (AnyRidge, MegaGen). Using resonance frequency analysis, implant stability values (ISQ, Osstell) were measured for each to ascertain stability for loading. Multi-unit abutments were placed on each implant based upon the tissue height and to redirect the screw access hole correctly within the envelope of the restoration. Titanium sleeves were then attached to each implant, and the carrier guide was used to accurately position the transitional prosthesis so that it could be secured to the implant sleeves with dual-polymerising composite material (STELLAR DC, Taub Products; Fig. 6). The process was repeated for the mandibular arch. The postoperative panoramic radiograph showed an excellent surgical result for both arches after the placement of 13 implants (Fig. 7). The transitional maxillary and mandibular restorations were evaluated for proper bite and occlusion (Fig. 8). After an adequate healing time (Fig. 9), the prostheses were removed and the soft-tissue maturation was evaluated relative to the multi-unit abutments (Figs. 10a & b).

Restorative phase

The conventional restorative phase would usually commence with intra-oral impressions to relate the implant positions to a master cast for the dental laboratory to design and fabricate the definitive prosthesis. From the master cast, it would be required to complete a verification index of the implants and determine the vertical dimension of occlusion, centric relation and bite registration using standardised prosthodontic protocols. However, current technology allows for the introduction of improved digital workflows that greatly aid the restorative phase. A combination of analogue and digital solutions were developed over time with the introduction of the iJIG (ROE Dental Laboratory). The initial purpose of the iJIG was to help with the design and fabrication of a full-arch restoration from an existing full-arch transitional restoration on multi-unit abutments. Simply, the iJIG is a verification jig with teeth. The device allows the clinician to lute passive sections together in the mouth, equilibrate the occlusion, capture the bite and pick up the intaglio soft tissue. This device provides all of the necessary records to fabricate a definitive or prototype restoration. It is also necessary to submit photographs of the full face and full smile, especially if aesthetic changes are desired.
The first-generation iJIG involved removing the existing transitional prosthesis for digitisation with a 360° scan with either an intra-oral scanner or a desktop scanner. The prosthesis was then reseated to scan the opposing arch and to digitally record the bite relationship. The first generation was adequate in concept, but very challenging for both the clinician and the dental laboratory technician trying to decipher the images of the cylinders and trajectory of the access holes to align the components. To overcome this difficulty, special iJIG analogues (ROE Dental Laboratory) were developed to accurately capture the positions of the implants and prosthetic components. The third generation utilised CAD software to develop digital tooth set-ups with anatomical teeth that were used to compensate for the equilibrated and worn teeth as a result of function during the healing phase. The fourth-generation iJIG is a prosthetic device that was designed based on the concept of “see your smile before surgery”. With CHROME GuidedSMILE, most patients receive a nearly true-to-form smile simulation and subsequent virtual tooth set-up based on STL files that mimic the simulation.

During the planning phase, the implants were positioned based upon the merging of intra-oral scans or digitised stone casts in combination with the transitional prosthetic design exported as an STL file. Therefore, the original implant and tooth planning phase rendered an ideal set-up.

Figs. 11a & b: The maxillary and mandibular iJIGs were sectioned and held together with a clear vacuum-formed overlay for seating and then intra-oral luting.
Figs. 12a & b: Each section of the iJIG was tightened on to the multi-unit abutments and luted together with either flowable composite or autopolymerising or dual-polymerising resin.

Figs. 13a & b: The iJIG prosthesis was reinserted, and a polyvinylsiloxane impression material was injected via syringe to capture the tissue interface and bite relationship. Fig. 14: A stone model was created from the impression to capture the location of the multi-unit abutments.
STL file based on the simulated smile design and stored in the computer until the final restorative phase began. The new STL files of surgical/prosthetic/intra-oral scans were merged with the original tooth set-up. The new iJIG was then fabricated based upon previously approved and actual transition prostheses worn during the healing phase. This replica was then used to register slight changes in implant position, soft tissue, occlusion and aesthetics. The maxillary and mandibular iJIGs were sectioned and held together with a clear vacuum-formed overlay for seating and then intra-oral luting (Figs. 11a & b). Each section was tightened onto the multi-unit abutments and approximated to be luted together with either flowable composite or autopolymerising or dual-polymerising resin (Figs. 12a & b). It was important that all sections were fully seated and passive. It is recommended that the fit of the prosthesis be verified with radiographs.

After careful luting, the full-arch try-in prosthetic was removed and tray adhesive applied to the intaglio surface and circumferential margins. The prosthesis was reinserted, and a polyvinylsiloxane impression material was then injected via syringe to capture the tissue interface and bite relationship (Figs. 13a & b). The prostheses with the impression material attached and the bite registration were then sent to the laboratory for processing. A stone model was then created from this impression to capture the location of the multi-unit abutments (Fig. 14). Once the dental laboratory received the new information, it was digitised and entered into the CAD/CAM software to complete the design (exocad DentalCAD, exocad). It is essential that the positions of the implants be accurately represented with the appropriate analogues within the software library. The digitally articulated maxillary and mandibular arches can then be ideally designed based on the updated information to correct any occlusal adjustments, tissue gaps, aesthetic considerations or functional changes (Figs. 15a & b).

Based upon the new virtual design, resin-based, 3D-printed clinical prototypes were fabricated and evaluated intra-orally (Figs. 16a & b). Recently, the fifth-generation iJIG introduced a more anatomical emergence design with the inclusion of an intra-oral soft-tissue scan. As previously described, the preoperative condition was captured with an intra-oral scan (Fig. 17). After the healing phase was completed, an intra-oral scan was utilised to record the positions of the multi-unit abutments and the surrounding soft tissue for both the maxillary and mandibular arches (Figs. 18a & b). Utilising the iJIG special scanning analogues attached to the implants, the entire prosthesis was then scanned and digitised extra-orally and merged with the opposing
The introduction of the soft tissue aids in the design of the prototype iJIG in establishing the material-to-ridge relationship of the final prosthetic tooth position, tissue contours, cantilevers, etc. The iJIG and resin try-in phase provides the clinician with essential information to deliver a more accurate and predictable definitive restoration.

The sixth generation requires the previously described seating procedures. The information was again introduced into the CAD/CAM software (3Shape) to complete the design of the definitive prosthesis, taking into consideration all changes in occlusion and aesthetics (Figs. 20a & b). The lateral views of the virtual design are illustrated in Figures 21a and b. The definitive screw-retained monolithic zirconia restorations were delivered for both arches. The screw access holes were first covered with PTFE tape and then filled with composite (Figs. 22a & b). The definitive prostheses can be visualised in the retracted views, showing an acceptable functional and aesthetic result (Figs. 23a–c).
The definitive prosthesis could be fabricated in zirconia, nano-ceramic bonded to titanium or nano-ceramic bonded to TRINIA (both Crystal Ultra materials, Digital Dental).

**Conclusion**

With careful diagnosis and treatment planning, it is possible to predictably manage full-arch immediate implant-supported restorations. The first of our two-part series described the 3D assessment of patient anatomy to provide the blueprint for tooth extraction, bone reduction and immediate implant placement with concomitant transitional restoration made possible with an innovative full-template guided solution. The article further described a stackable guide system that provided a combination of a drill guide, bone reduction guide, implant insertion guide and connection to the full-arch maxillary restoration. The second part of the two-part series described the steps necessary to complete a simultaneous dual full-arch prosthetic reconstruction after confirmation of osseointegration and satisfactory soft-tissue maturation surrounding the multi-unit screw-receiving abutments. Conventional analogue prosthetic protocols have required intra-oral impressions that capture the implant abutments within a stone master cast to be mounted on to an articulator at the proper vertical and centric relation position. The dental laboratory technician was then tasked with creating a wax-up with denture teeth to confirm the bite, lip support, phonetics and aesthetics. From this analogue...
protocol, a screw-retained definitive restoration was completed. It was not until a digital workflow and the advent of CAD/CAM software and milling machines that the analogue wax-up was then digitised to create a virtual design and STL file for fabrication of full-arch monolithic zirconia restorations. To enhance the digital workflow, the evolution of the time-saving iJIG device was presented.

As previously described, immediate loading of dental implants for full-arch reconstruction offers many advantages over delayed treatment alternatives, but it does require a prefabricated prosthesis at the time of surgery. For the purposes of this article series, the transitional restorations were all digitally designed and produced with a nearly true-to-form smile simulation for delivery via a stackable guide system at the time of surgery.

The current iteration of the iJIG manages the small differences from the original transitional restoration to the desired definitive restoration with an accurate and time-saving innovation. The iJIG can potentially reduce restorative time to three visits. The iJIG is compatible with most implant systems, including those of MegaGen, Nobel Biocare, BioHorizons, Neodent, Zimmer Biomet (former Biomet 3i implants), Straumann, Hiossen, Thommen Medical and Keystone Dental. Other systems, which include those of Zimmer Biomet (former Zimmer implants), Implant Direct, CAMLOG, Dentsply Sirona (Astra Tech Implant System), MIS Implants Technologies, Straumann and Paltop, require specific original equipment manufacturer multi-unit abutment replicas in order to accurately scan the prosthesis.

The present case study required bone reduction to achieve the necessary restorative space for the completion of successful dual full-arch FP-3 prostheses, utilising the CHROME GuidedSMILE concept with advanced digital workflows. The same full-template guided protocols have also been demonstrated in cases where preservation of the alveolar and interproximal bony architecture was desired, which resulted in an FP-1 prosthetic (pink-free) design, or when zygomatic implants were to be used to support a fixed restoration necessitated in the severely atrophied maxillary arch. More research and additional multicentre studies will help in understanding the long-term success of these innovative surgical and restorative protocols.

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