The evolution of digital technologies in dentistry has paved the way for the development of simplified and predictable protocols in the field of restorative dentistry. Digital dental technologies have allowed the seamless delivery of complex treatments.

Proper treatment planning protocols are the foundation of any fixed restoration in the arch involving dental implants. The data from the CBCT scan and intra-oral surface scans, combined with the use of CAD software, allows the simplification of workflows, including diagnostic facially driven mock-ups, restoration-driven implant treatment planning, and the design and fabrication of surgical guides. The design of the provisional and permanent prostheses and the design of the master die model can all be done on CAD software and then manufactured with either 3D printing or milling. The prosthetic design can be visualised, planned and even designed prior to the patient even attending for the surgical phase of treatment. An accurate and predictable outcome of the implant surgery as well as of the restorative rehabilitation is realised this way.

Case report

The following case study demonstrates a scenario in which a fully digital workflow was utilised with two provisionnalisation phases to rehabilitate the full maxillary arch.

Diagnostic record collation and treatment planning phase

A 79-year-old patient presented with the chief complaints of mobile teeth and occasional discomfort from the areas around his existing maxillary fixed partial prosthesis. His medical history was unremarkable. The clinical and radiographic examinations indicated moderate to advanced bone loss affecting many of his maxillary and mandibular teeth and secondary decay on the abutments of his fixed prosthesis (Figs. 1a & b). Teeth #15, 16 and 28 had a poor prognosis and were planned for extraction. The goal of the treatment was to rehabilitate the maxillary arch with a combination of crowns and implant-retained restorations to provide the patient with a fixed solution.

In the initial treatment phase, teeth #16 and 28 were extracted and the remaining dentition was periodontally treated (Figs. 2a & b). After the initial clinical examination and treatment, further information was collated. This in-
cluded the use of 3D CBCT scanning for the pre-surgical planning and of intra-oral scanning. Digital impressions before and after removal of the original porcelain-fused-to-metal (PFM) fixed partial prosthesis were taken, as well as of the patient’s occlusion. Rough preparation of the abutment teeth was also completed prior to acquisition of the subsequent intra-oral scan.

The accuracy of image registration (superimposition of the intra-oral scan and CBCT scan data) can be enhanced by prior removal of the PFM fixed partial prosthesis to reduce radiographic scatter caused by the metallic components of the prosthesis and by the use of radiographic reference markers (Figs. 3a & b). A composite such as G-ænial Universal Injectable (GC), with a radiopacity of 250% aluminium, does not result in radiographic scattering during CBCT scans.

**Treatment plan**

After collation of the information, the initial treatment plan was formulated. It involved guided surgical placement of implants in sites #16, 14, 11, 21 and 25. A bone graft was also planned for site #11 owing to bony defects. A two-stage surgical protocol was chosen for proper integration of the implants in sites #11 and 21. Immediate provisionalisation was to be performed with a 3D-printed provisional fixed partial prosthesis (Temp PRINT, GC) extending from site #15 to site #24. The existing shape and contours of the current failing fixed partial prosthesis were copied from the preoperative intra-oral surface scan to create the provisional fixed partial prosthesis. After implant integration, a second phase of provisionalisation was foreseen with individual provisional restorations (Temp PRINT) on the implants and natural teeth. This would allow verification of aesthetics and occlusion, soft-tissue management and extraction of tooth #15. It was planned to use lithium disilicate and monolithic zirconia for the permanent restorations on both the natural teeth and implant abutments.

**Digital implant planning and surgical guide fabrication**

Digital data from the three scans—the CBCT scan and the intra-oral surface scans before and after fixed partial prosthesis removal—was accurately merged. This enabled
virtual planning of the number, position, angulation and access position of the implants following a restoratively driven protocol (Figs. 4a & b).

Based on the planned implant positioning (Fig. 5), a surgical guide was designed with the dedicated software. Master sleeves from the guided surgical system were placed and fixed to the printed guide/framework.

The design of the previous PFM fixed partial prosthesis was also copied and replicated in the digital planning of the provisional fixed partial prosthesis. It was then printed using the Asiga MAX UV printer and Temp PRINT (medium shade) set at 50 µm on the 3D printer.

Guided implant surgery and first provisionalisation phase
All five implants were placed following a fully guided surgical protocol with the surgical guide (Figs. 6a & b) and primary stability was confirmed. A flap was then raised at sites #11–21, and a bone graft with bovine cancellous particulate was placed and covered with a porcine collagen membrane. Cover screws were placed, and primary closure was established with PTFE sutures after a relieving incision was performed. At the other implant sites (#16, 14 and 25), healing abutments were placed (Figs. 7a–c). The 3D-printed provisional fixed partial prosthesis was then cemented with Fuji TEMP LT (GC) to the remaining natural teeth (Figs. 8a & b).

A healing period of 16 weeks allowed complete osseo-integration of the implants. During this period, tooth #24 (maxillary left first premolar) developed signs and symptoms of pulp necrosis. Hence, it was endodontically treated (Fig. 9).

Second provisionalisation phase after implant integration
Once the 16-week healing phase was completed and the implants were integrated, the restorative phase could
be initiated. The patient confirmed that he was happy with the shape and occlusion of the initial provisional fixed partial prosthesis (Figs. 10a & b). The aesthetic and occlusal scheme could therefore be replicated in the second phase of provisionalisation.

A pre-preparation intra-oral surface scan was taken with the healing abutment and provisional fixed partial prosthesis in situ (Fig. 11). The provisional fixed partial prosthesis was then removed, and preparation of the abutment teeth finalised and remargined to the healed gingival tissue levels. The second stage of implant surgery at sites #11 and 21 was completed using a soft-tissue diode laser. The implants were exposed and the cover screws removed.

An emergence profile scan was taken immediately after the healing abutments were removed to record gingival contours around the implant before any collapse of the tissue. Next, the full maxillary arch was scanned with digital scan bodies in place to capture the implant position accurately (Figs. 12a–c). All other prosthodontic records, including the maxillomandibular relationship record and the opposing arch, were also captured with the intra-oral scanner before replacing the provisional fixed partial prosthesis.

All the intra-oral scans were taken following the Mak optimised scan strategy (MOSS), allowing accurate stitching of intra-oral scan images. In soft-tissue areas, the availability of landmarks is often limited; MOSS uses a specific

Figs. 15a & b: Completed provisional restorations fitted on to the printed models to allow the refinement of the contact points and occlusal contacts, palatal (a) and labial (b) views. Figs. 16a & b: After removal of the provisional fixed partial prosthesis from the first provisionalisation phase (a). Tooth #15 was extracted (b).
scan path with or without markers for enhanced scan accuracy and was especially designed for cases with few teeth to correlate to. All the digital data was then sent to the ceramist for the fabrication of the second set of provisional restorations.

The provisional restorations were printed with Temp PRINT and characterised with OPTIGLAZE color (GC). Provisional abutment cylinders were utilised for the implant-retained restorations. The contours of the provisional restorations retained on implants #11 and 21 as well as of the pontic on tooth #15 were designed and fabricated to shape the soft tissue for optimal support (Figs. 13–15b).

After removal of the provisional fixed partial prosthesis, all the abutments were cleaned and tooth #15 was extracted (Figs. 16a & b). The provisional implant restorations, fabricated with direct screw access, were torqued to the manufacturer’s recommendation. All the other provisional printed restorations were cemented with Fuji TEMP LT (Figs. 17a–19b). The soft tissue was prosthetically shaped and allowed to heal for a period of three months before finalisation of the rehabilitation with the definitive restorations.

Conclusion

The case presented illustrates how advances in digital technologies can provide clinicians with the tools for diagnosis, treatment planning, and the execution and provision of dental restorative procedures in a truly transformative way. Simplification of clinical protocols, increased accuracy over conventional analogue techniques, and improved patient comfort and outcomes are compelling reasons for the use of a fully digital workflow in the field of restorative and implant dentistry.

about

Dr Anthony Mak obtained his dental degree at the University of Sydney in Australia and then went on to complete his postgraduate diploma in oral implantology. He graduated with multiple awards and has worked with some of Sydney’s most renowned practitioners. His interests lie in dental technologies and advances in materials and techniques. He has a unique understanding of CAD/CAM dentistry and currently owns two practices in metropolitan Sydney focusing on comprehensive and implant dentistry. Dr Mak has a thorough understanding of direct versus indirect dental restorations and has lectured internationally on the topics of aesthetic and digital dentistry. He is a sought-after speaker and a key opinion leader for several global dental companies.

Dr Andrew Chio graduated as a dentist at the top of his year from the University of Melbourne in Australia in 1995. On graduation, he undertook his dental internship at the Bendigo Base Hospital before spending the next one and a half years working in a rural hospital in Nepal. He is the principle dentist of Arawatta Dental Centre in Carnegie in Australia and an active member of various dental associations. He is a lecturer and gives advanced hands-on training to dentists in specific areas of restorative dentistry.