This case report describes a novel approach combining orthodontic and implant digital treatment planning workflows to enable prosthetically driven implant placement before orthodontic treatment is performed or completed. The computer-assisted implant placement is performed using a static surgical guide based on the future positions of the teeth after completion of orthodontic treatment. This innovative approach allows for select partially edentulous patients to undergo fixed prosthetic rehabilitation before orthodontic treatment is completed. Int J Prosthodont 2022 September 22. doi: 10.11607/ijp.7684

Digital technology has revolutionized dental treatment planning and execution. Though each clinical field in dentistry continues to use this growing technology to innovate and improve on different aspects of their daily practice, the full potential of the application of digital technology for multidisciplinary treatment planning has not been fully unraveled. Orthodontic and dental implant treatment planning have been individually revolutionized with the introduction and development of digital technology, with digital workflows and guided implant placement being widely reported in the literature. The precision and accuracy of guided implant surgery have shown promising results, offering predictable implant positioning. Digital planning of orthodontic treatment and clear aligners has also demonstrated predictable rehabilitation when limited tooth movement is required.

Achieving a prosthetically driven implant position can necessitate space management using orthodontic appliances to move the surrounding teeth. Different multidisciplinary approaches combining orthodontic and implant treatments have been reported. These studies showed an identical pathway/workflow by finalizing the orthodontic treatment first, then proceeding to the implant placement. Although these sequenced treatments have been reported as predictable, the long edentulous

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period before implant restoration represents one of its major disadvantages. Virtual orthodontic and implant workflows represent treatment options that have facilitated the visualization of multiple possible treatment outcomes. Combining orthodontic and implant digital planning can significantly reduce the treatment time frame. With this kind of treatment planning, predictable guided implant placement can be performed at the same time as clear aligners shift teeth with predictable movement (Invisalign).

This case report presents a novel application utilizing digital technology to combine orthodontic and surgical implant treatment planning to offer an innovative treatment option, reducing the edentulous period and overall treatment time frame for the patient.

Case Presentation

The CARE Case Report Guidelines were followed for the publication of this clinical case. The patient signed the Harvard Dental Center treatment consent forms, as well as the treatment-specific consent form. An adult male patient presented to the Harvard School of Dental Medicine implantology clinic with missing teeth 33 to 42 (FDI) as the result of a traffic accident. The patient also had a coronal fracture of tooth 13. The patient sought emergency dental care immediately after the accident, and the remaining roots of the fractured mandibular anterior teeth were deemed nonrestorable and were thus extracted (Fig 1). An implant-supported restoration treatment was then planned for the patient, and the canine in position 13 was planned to be crowned. Furthermore, the patient presented with a congenitally missing tooth 12 and misaligned maxillary anterior teeth, which were unsatisfactory to the patient. The patient stated that he had previously contemplated orthodontic treatment, as his career requires a high frequency of public speaking. The patient was recommended to complete orthodontic treatment before implant treatment began. The patient expressed his desire to do the orthodontic treatment only if it would not delay his implant rehabilitation. Consultation with the Orthodontic Department at Harvard School of Dental Medicine was done. Accordingly, the patient was offered a novel treatment approach that would allow for accurate implant placement and restoration before orthodontic treatment was started. The patient had no significant medical conditions, was not taking any medications, and did not have any allergies.

Digital Planning

Digital planning is shown in Fig 2. A digital diagnostic impression of the maxillary and mandibular arches was made using an intraoral scanner (iTero, Align Technology). Orthodontic digital planning was performed according to the ideal desired orthodontic tooth position. An Invisalign workflow was established, and clear aligners were digitally planned and 3D printed. Stereolithographic (STL) files of the final tray and teeth position were exported from the Invisalign software and imported into CAD/CAM software (Straumann CARES Visual, Institut Straumann). A digital diagnostic wax-up was created to replace the missing mandibular teeth and the congenitally missing tooth 12. Establishing an esthetic wax-up required the redistribution of the maxillary and mandibular anterior teeth positions. The digital wax-up was 3D printed and tried-in in the patient’s mouth for esthetic and functional evaluation.

A maxillary and mandibular CBCT scan (i-CAT, Imaging Sciences) was then performed, and the images were stored as Digital Imaging and Communications in Medicine (DICOM) files. The DICOM files were imported to implant planning software (coDiagnostiX, Dental Wings). The bone and teeth structures were isolated using the segmentation tool, and a clear identification of the anatomical landmarks was achieved. The STL file of the digital intraoral impression and the STL file of the diagnostic digital wax-up were both registered onto the DICOM file using the posterior unchanged dentition as common reference points. The implant positions were digitally planned according to the prosthetic digital wax-up and to the soft and hard tissue anatomy. The position of the implants corresponded to the ideal position of the mandibular anterior teeth in order to align with the future position of the maxillary anterior teeth after the completion of the orthodontic treatment. As expected, an ideal implant position was not permitted for tooth 12 due to a lack of mesiodistal space between the roots of the two neighboring teeth. In the mandible, two implants were planned to support a fixed-screw-retained bridge to replace the missing teeth from 33 to 42. Two 3.3- x 12-mm implants (Standard Narrow Neck CrossFit, Tissue Level, Straumann) were digitally planned for the teeth 33 and 41 positions in order to support a screw-retained fixed partial denture restoration, with tooth 42 as a cantilever. At this stage, it was possible to identify anterior bone resorption in the mandible that required guided bone regeneration (GBR) grafting procedures along with simultaneous implant placement. Digital analysis of this virtual planning revealed that the initial and planned final distribution of the mandibular teeth did not prevent the desired implant positioning. Therefore, a guided implant surgery could occur at the same time as the orthodontic treatment according to the final prosthetic desired outcome and the position of the teeth. However, the implant in the tooth 12 position needed more mesiodistal space before proceeding to the guided implant surgery. The required minimal root movement was then digitally calculated in order to allow a prosthetically driven implant position in an adequate 3D space. A mandibular surgical guide was created and 3D printed to perform a guided surgery of implants 22.
and 25. Clear aligners (Invisalign) were also obtained and delivered to the patient with instructions for use.

**Implant Surgery**

Five months following tooth loss/extraction, the implant surgery on the mandibular arch was performed (Fig 3). Adequate seating of the surgical guide was confirmed visually through the designed inspection windows. After local anesthesia (2% lidocaine hydrochloride with 1:100,000 epinephrine, Henry Schein), a crestal and sulcular incision was performed, and two vertical releasing incisions were made anterior to the mental nerve foramen. A full-thickness flap was elevated, followed by degranulation of the surgical site. The tooth-supported surgical guide was accurately positioned. The osteotomy was performed according to the digital planning and the guided drilling protocol. Two implants were placed with an sCAIS approach using the surgical guide. To prevent surface exposure of the implants, a GBR procedure was performed. Autogenous bone chips were locally harvested and positioned on the exposed surface, then covered with a mix of deproteinized bovine bone material.
Fig 3  (a) During surgery, the alveolar crest was exposed and showed advanced bone ridge resorption resulting from the trauma. (b) A guided implant surgery was performed to place two implants (c and d) followed by guided bone regeneration to correct the bone deficiency. (e) Suturing with tension-free closure. (f) Postoperative panoramic radiograph showing the two implant positions after surgery.

Fig 4  Posttreatment views. (a) Frontal view. (b) Panoramic radiograph. (c) Occlusal views.
(DBBM; BioOss, Geistlich Pharma North America) and freeze-dried bone allograft (FDBA; RegenerOss Allograft, Zimmer Biomet Dental), as well as with a double-layer BioGide membrane (Geistlich Pharma North America). Adequate tension-free primary closure was obtained after a periosteal releasing incision. The orthodontic clear aligners were modified according to the surgical site to prevent any soft tissue pressure or contact, and postoperative instructions were given. Postoperatively, the patient was prescribed amoxicillin 500 mg to be taken every 8 hours for 5 days. During the healing time, the patient was instructed to follow his orthodontic treatment protocol. The patient was seen at 1-week intervals for the first month and then once a month thereafter. After 3 months, a provisional screw-retained restoration was delivered to the patient.

At 1 year postoperation, the space around tooth 12 was clinically adequate to undergo the guided implant surgery. Removable orthodontic appliances for retention were delivered to maintain postorthodontic tooth positions. A maxillary CBCT scan (Kodak 9000 Extraoral Imaging System, Carestream Health) was performed. The DICOM file was imported into the implant planning software. The STL file of the digital prosthetic wax-up was superimposed on the DICOM file using the unchanged posterior dentition as common references between

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**Fig 5** Step-by-step workflow for the case treatment plan.
two files. An implant (Small CrossFit, Bone Level Tapered, Straumann; 2.9 x 12 mm) was digitally planned according to the desired prosthetic wax-up and the hard and soft tissue anatomy. The 3D space and the digital implant position were satisfactory for performing the implant surgery. A tooth-supported surgical guide was designed and 3D printed. After local anesthesia, a full-thickness flap was elevated, and a degranulation of the surgical site was performed. The tooth-supported guide was positioned, and adequate seating was verified using designated inspection windows. After following the recommended guided drilling protocol, the implant was placed according to the preplanned virtual position. The implant fenestration was grafted with a layer of autogenous bone chips and covered with DBBM and a double-layer membrane (BioGide®, Geistlich Pharma North America). Adequate periosteal incision allowed the tension-free primary closure of the site. Postoperative instructions were given to the patient. Follow-up appointments were conducted without any complications reported. The clear aligner was modified to prevent any pressure or soft tissue contact with the surgical site. After 3 months, the orthodontic treatment protocol was completed. The patient was given postorthodontic removable appliances for stabilization. The movement of the teeth was satisfactory to the prosthetic wax-up and the desired esthetic outcome. A provisional restoration was delivered on the maxillary right lateral implant in order to shape the emergence profile. After 6 weeks, a final digital impression of the maxillary and mandibular implants was performed, and the final screw-retained prosthesis was delivered, with an outcome that was similar to the planned prosthetic wax-up. A final tooth-supported crown was also delivered on tooth 23. A summary of the workflow is illustrated in a step-by-step approach in Fig 5. The patient reported being very satisfied with the treatment outcome. He also indicated that he was happy to have completed the orthodontic treatment for optimal results, but still would not have done it if it meant delaying his implant-prosthetic rehabilitation.

DISCUSSION

A crucial criterion for the success of implant restoration is the correct 3D positioning of the implant. Successful multidisciplinary treatments require a specific approach in which the timing of each specialty’s intervention is fundamental. Orthodontic and implant-prosthetic rehabilitations are two specialties that are often combined to achieve optimal esthetic and functional outcomes. It is standard practice that orthodontic treatment be carried out first in order to finalize tooth position and to obtain an adequate prosthetic and biologic space before implant surgery and final prosthetic rehabilitation are performed. Once the orthodontic treatment is completed, a prosthetic wax-up of the teeth to be replaced is designed, and implant surgery is performed according to the desired prosthetic outcome. Successful esthetic and biologic outcomes have been reported using this workflow sequence. However, the time frame of this approach represents one of its main disadvantages. Partially edentulous patients often show reluctance to undergo the indicated orthodontic treatment before implant and prosthetic rehabilitation because of the extended treatment time, even when a better esthetic outcome can be achieved.

The development of digital technology has revolutionized the approach in the orthodontic and implant fields, offering new pathways for multidisciplinary treatments. In orthodontics, the combination of digital technology and clear aligners as a treatment has been widely reported in the literature. Studies have reported it as a successful and predictable alternative to conventional fixed appliances for mild to moderate malocclusion. Treatment with clear orthodontic aligners also seems to offer a faster treatment time frame, better gingival health compared to the fixed appliance, and higher patient satisfaction. Moreover, one of the key advantages of this treatment is to digitally predetermine the final desired esthetic and tooth position outcome. The capacity to digitally previsualize the final outcome and the predictability of the treatment are common characteristics of the digital technology used in the implant field. Indeed, computer-guided implant surgery is now commonly reported in the literature. An implant software is used to digitally plan an implant position according to a predetermined prosthetic wax-up and desired outcome. A surgical guide is digitally designed and 3D printed to perform a guided implant surgery aiming at transferring the digital implant position in the patient’s mouth. Successful accuracy and precision with this technique have been reported, especially when a tooth-supported guide is used. The static CAIS protocol followed in this case (Straumann Guided Surgery Implant System, digital planning with coDiagnostix) for the placement of two implants has been shown in a recent randomized clinical trial to result in high levels of precision with regard to both implant position and parallelism. The mean (± SD) 3D deviation was 1.04 (± 0.67) mm at the platform, 1.54 (± 0.79) mm at the apex, and 4.08 (± 1.69) degrees in the angle. The deviation in angle between the two placed implants (parallelism) in static CAIS was found to be 4.32 (± 2.44) degrees. Although such minor deviations are still to be anticipated, at this extent, they fall within the comfort zone of compensation with the design of the final prosthesis. Therefore, combining both technologies seems to offer a new digital workflow in the orthodontic and implant rehabilitation multidisciplinary treatment. Such a workflow could offer significant advantages when indicated, not only by allowing the timely overlap
of implant and orthodontic therapy, but also by potentially bringing up important synergies between the two treatments. For example, an early implant placement could enhance the orthodontic treatment possibilities by offering rigid anchorage points for faster and more complex orthodontic movements.20,21 Furthermore, the surgical intervention for implant placement could potentially be combined with interventions for surgical acceleration of the orthodontic movement, such as corticotomy, when indicated.22 As described in the present protocol, a common final predetermined outcome is designed for both specialties. From this preplanned digital wax-up, the creation of clear aligners and the planning of the digital implant treatment are performed at the same time. If the 3D implant position allows it, the guided implant surgery can be done before the end of the orthodontic treatment. A similar approach has been reported previously with conventional orthodontic fixed appliances.10,23 Furthermore, placing implants before rendering the orthodontic treatment does not seem to prevent the planned and desired tooth movement.12 It is important to note that case selection is of paramount importance for the success of this technique. It is only indicated in highly motivated and compliant patients. Furthermore, it requires excellent and continuous communication between the implant and orthodontic teams. Limitations of this technique include the required access to the final STL file of the orthodontic treatment. This might be complicated in some cases, and in many situations the files cannot be provided before the patient is committed to the orthodontic treatment. There is also the potential of the patient not finishing the planned orthodontic treatment. In the present case, the treatment team prepared for the prosthetic outcome of the patient abandoning orthodontic treatment by digitally planning the scenario. It was determined that even in the event of orthodontic abandonment, this case could still have been restored successfully with angled abutments. Furthermore, the length of treatment time requires close follow-up with patients. After placement of the implant in tooth position 12, the patient moved to a different city, and when he returned, poor oral hygiene was noted around the implant, which resulted in peri-implant mucositis. This was reversed with prophylactic treatment, and oral hygiene instructions were reinforced.

CONCLUSIONS

The patient expressed his extreme satisfaction with the treatment choice and outcome. Additionally, he stressed the fact that if he would have had to wait for the completion of orthodontic treatment to receive his implant rehabilitation, he would have certainly declined to undergo orthodontic treatment. This innovative multidisciplinary workflow offers a significant reduction in the time frame of the treatment, which represents an impactful advantage for clinicians and offers new solutions for partially edentulous orthodontic patients.

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REFERENCES


