Combining All-on-4 Treatment with CT-Guided Technology: Technique and Report of Three Cases

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Abstract: No longer merely a concept for the future, the use of digital technologies in dentistry has become common practice today. Computed tomography (CT)-guided dental implant surgery has greatly expanded over the past decade as concepts and techniques have become increasingly refined and more implant manufacturers have adapted their implant systems to these new technologies. The All-on-4® technique for dental implant placement and restoration, while developed some two decades ago, has recently generated increased interest as a highly functional, esthetic, cost-effective alternative for a large group of patients who could benefit from a full-arch, implant-supported fixed restoration. The authors ask, "Are these two technologies a marriage made in heaven?" This article describes the All-on-4 CT-guided surgery technique and reports on the treatment findings on three patients, each with different prosthodontic management.

Implant placement using "guided" technologies has been shown to have greater accuracy and precision when compared to freehand techniques.[1-7] This can reduce the incidence of untoward involvement with vital anatomic structures and minimize patient morbidity.[8-16] Using proprietary implant-planning software, implants can be "virtually" placed at known pre-planned depths and angulations in three dimensions. Surgical guides are then fabricated from the virtual treatment plan for highly accurate implant placement into the planned implant positions.

This use of virtual, guided technologies contrasts with the practice commonly employed for the placement of dental implants using the conventional All-on-4® (Nobel Biocare, www.nobelbiocare.com) protocol, a concept that has gained acceptance for complete arch restoration. Traditionally, after a clinical evaluation, the All-on-4 surgical workflow first involves a standard panoramic and/or a computed tomography (CT)/cone beam CT (CBCT) evaluation of the patient's anatomy with routine pre-treatment planning. This leads to surgery involving a full-arch incision with full-arch flap elevation. If necessary, alveolar crest leveling is performed. A paralleling guide is used to verify implant angulation. Osteotomies and implant placement are done freehand. Implants are commonly placed at 30-degree angles (M-4 maxilla and V-4 mandible), and angled abutments are then placed as needed. The implants are usually immediately loaded by retrofitting an existing or new denture prosthesis or by placing a fixed provisional restoration based on an abutment-level impression taken at the time of surgery. The provisional restoration is screw retained.

The use of computer-aided design/computer-aided manufacturing (CAD/CAM) and digital technologies in oral and maxillofacial surgery and dentistry is no longer a futuristic concept. These technologies are being commonly used in dental practice today.[17,18] Over the past decade the use of CT-guided dental implant surgery has increased significantly as concepts and techniques have become more refined and many implant manufacturers have adapted their implant systems to these new technologies. The All-on-4 concept for dental implant placement and restoration has been discussed for many years. Recently, the technique has generated increased interest as a highly functional, esthetic, more cost-effective alternative for a larger group of patients who could benefit from a full-arch, implant-supported fixed restoration.

The purpose of this article is to describe the All-on-4 CT-guided surgery technique and report on the findings of three patients treated. Each of the cases had different prosthodontic management.

Technique

CT-guided implant planning and surgery is a restoratively driven treatment plan. It first involves planning an ideal dental restoration for a patient; this may be a complete denture or, for a partially edentulous patient, a diagnostic wax-up of the planned restorations. In the typical guided surgery workflow, the patient then wears an acrylic resin appliance ("scan prosthesis"), which incorporates the ideal anatomy and position of the planned restoration(s), while having a CT/CBCT scan taken of his or her jaw. Various types of fiducial markers are embedded in the scan prosthesis.

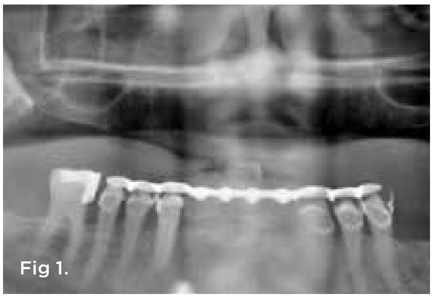
The digital imaging and communication in medicine (DICOM) images generated from the scans are then imported into third-party proprietary softwares. The softwares use the fiducial marker points to align the data generated from the scan(s), creating computer images that accurately relate the planned restoration(s) to the patient's underlying bony anatomy. Implant positions and angulations can then be precisely planned in a virtual environment.

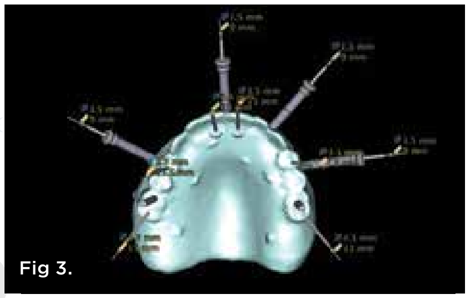
This virtual treatment plan is then sent to a manufacturer or laboratory for fabrication of an appliance that is used at the time of surgery to accurately place the implants in their planned position(s). Most larger implant manufacturers offer guided surgery-specific instrumentation for flapless implant placement. When desired and indicated, techniques and armamentarium are available for extractions, bone reduction, immediate implant placement, and immediate loading, all of which are commonly used in the All-on-4 protocol.

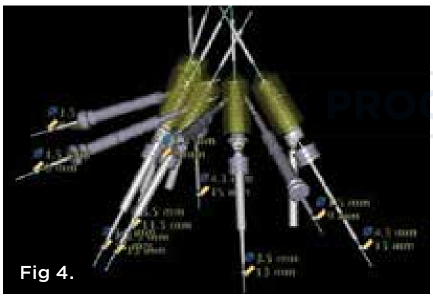
Patient 1

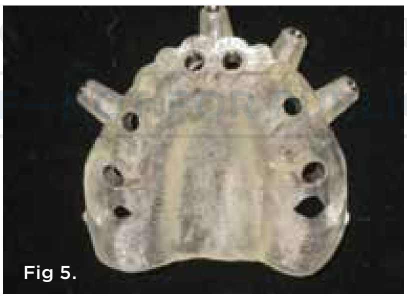
A 50-year-old fully edentulous man presented desiring a full-arch, fixed maxillary restoration. He had been wearing a maxillary denture for 6 years after prematurely losing his teeth from decay and periodontal disease. The denture had never been relined. His past medical history was noncontributory. Finances were a problem for the patient.

An initial clinical examination that included conventional dental and panoramic radiographs was performed (Figure 1). After an extensive discussion of the surgical and prosthodontic options, an All-on-4/6 option with a retrofit of his existing maxillary denture as an immediate hybrid provisional restoration was planned. First, a hard denture reline was performed on his existing maxillary









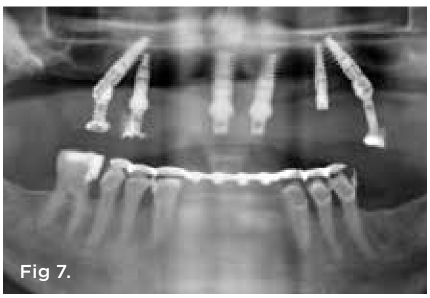


Fig 1. *Patient 1.* Preoperative radiograph, fully edentulous maxilla. **Fig 2.** Hard relined maxillary denture, gutta percha fiducial markers inserted. **Fig 3.** Virtual treatment plan: six implants, angled abutments in place. **Fig 4.** Virtual treatment plan, left side. Note 30-degree angled posterior implant. **Fig 5.** Surgical guide created stereolithographically from the treatment plan. **Fig 6.** Surgical guide secured in place with guided stabilization pins. Implants placed fully guided to planned depth and angulation with implant mounts. **Fig 7.** Postoperative panoramic radiograph. Note healing abutment on implant maxillary left posterior implant site, not immediately loaded. **Fig 8.** Maxillary denture adjusted and retrofitted to allow for titanium abutments to be embedded with light-cured acrylic resin. **Fig 9.** Provisional restoration secured with prosthetic screws as an immediate load.

denture for ideal denture adaptation to the mucosa. An occlusal registration between the denture and opposing arch was fabricated. Gutta percha points were added to the maxillary denture as fiducial markers (Figure 2). As per the double-scan protocol, two appropriate scans were then taken—one of the patient with the denture and occlusal registration in place and a second one of just the denture. The DICOM sets were then imported into the NobelClinician® (NobelBiocare) planning software. Because of the atrophy of the maxillary ridge in width, placement of six implants was planned virtually. One 30-degree, regular-diameter angled implant was treatment-planned posteriorly on each side; four narrow-platform, vertically positioned implants were planned in the anterior areas (Figure 3 and Figure 4). Once completed, the plan was digitally sent to the manufacturer for fabrication of a stereolithographic surgical guide (Figure 5).

At surgery, the surgical guide was properly positioned using an occlusal registration between the guide and the opposing arch. The appliance was stabilized using stabilization pins. Implant-specific instrumentation was used to place the six planned implants to full depth and accurate direction using guided-surgery techniques with implant mounts (Figure 6). Thirty-degree stock abutments were placed on the two posterior implants, and 0-degree stock abutments were placed on three of the four anterior implants. A healing abutment was placed on one implant because of suboptimal initial stability (Figure 7). Temporary titanium sleeves were then placed on the remaining five abutments, two at a time. The denture was modified by creating access openings for the titanium sleeves (Figure 8). Light-activated acrylic resin was used to attach the titanium sleeves to the modified denture. Once trimmed and adjusted, the denture was secured using prosthetic screws (Figure 9). It should be noted that one vertical implant—not the one with suboptimal initial stability—failed during the provisionalization period and was removed and not replaced. The implant that was not initially loaded went on to osseointegrate and was successfully used in the final restoration.

Patient 2

A 65-year-old woman presented with multiple missing and nonrestorable mandibular teeth. She refused to wear a full mandibular denture and wanted a fixed restoration. Her medical history was noncontributory. Finances were an issue for her.

Standard dental records and radiographs (Figure 10) were taken as if the patient were to receive an immediate mandibular denture after extractions. A finished complete mandibular denture


Fig 10.


Fig 11.

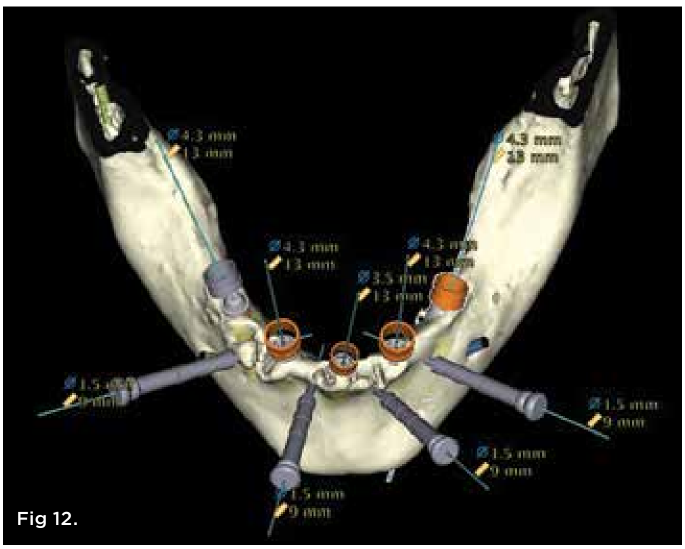


Fig 12.

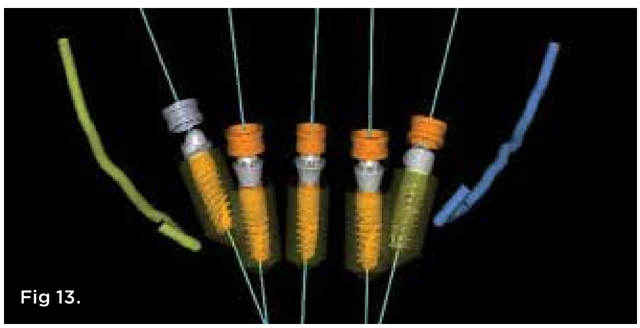


Fig 13.

Fig 10. *Patient 2.* Preoperative panoramic radiograph prior to extractions. **Fig 11.** Multiple-piece radiographic guide, two pieces. Double-scan technique planned. **Fig 12.** Full-arch treatment plan: two 30-degree posterior implants, three vertical anterior implants. **Fig 13.** Treatment plan, anterior view, five implants planned.

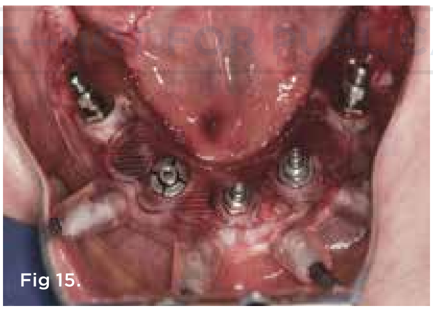
was fabricated by the dental laboratory for later modification as a provisional fixed restoration. A multiple-piece scanning prosthesis with gutta percha fiducial markers and an occlusal registration was fabricated by the dental laboratory according to the manufacturer's guided-surgery protocol (Figure 11). CBCT scans (iCat®, Imaging Sciences International, LLC, www.i-cat.com) using the double-scan technique were taken with the patient wearing this appliance and occlusal registration. The CBCT data was converted into DICOM images and imported into the NobelClinician software for guided-surgery treatment planning. One 30-degree angled implant was treatment-planned posteriorly on each side. Three vertical implants were planned anteriorly, two in planned extraction sockets (Figure 12 and Figure 13). The completed plan was digitally sent to the manufacturer for surgical guide fabrication.

Under intravenous sedation and local anesthesia, the remaining mandibular teeth were extracted with minimal trauma (Figure 14). A bite registration was used to correctly position the surgical guide. Stabilization pins were then placed to secure the surgical guide. Implant-specific instrumentation was used to prepare the appropriate osteotomies and place five implants, fully guided, using implant mounts through the surgical guide to the planned depth and angulation (Figure 15). Thirty-degree stock abutments were placed on the two posterior implants, and 0-degree stock abutments were placed on the three anterior implants (Figure 16). At the time of surgery, open-tray impression copings were placed on the abutments, and an abutment-level impression was made of the postsurgical implant positions (Figure 17). Closed-tray impression copings were used to make an occlusal registration between the arches. The above impression and occlusal registration, along with the immediate mandibular denture and prior-fabricated mounted casts, were sent to the dental laboratory for overnight retrofitting of the mandibular denture. The following morning, the retrofitted acrylic provisional restoration was returned and secured on the implants in the patient's mandibular arch by prosthetic screw retention (Figure 18 and Figure 19). A minimal occlusal adjustment was necessary. The patient was discharged with explicit dietary instructions regarding extractions and immediate loading of dental implants.

Patient 3

A 62-year-old woman presented with a nonrestorable maxillary dentition, which was indicated for full-mouth extraction. She wanted a full-mouth, implant-supported fixed restoration with an immediate provisional restoration. Her past medical history was negative. Finances were a concern for her.

The patient was evaluated and worked-up clinically and radiographically (Figure 20). Maxillary and mandibular diagnostic casts were made and mounted on an articulator. An ideal diagnostic wax-up of the planned maxillary dentition was created and converted into a multiple-piece hard acrylic scanning appliance. Gutta percha points were added as fiducial markers (Figure 21). CBCT scans were taken using the double-scan technique. The DICOM images were then imported into the NobelClinician software. Six implants were treatment-planned (Figure 22 and Figure 23). The plan was sent to the manufacturer via the Internet for fabrication of a stereolithographic surgical guide based on the virtual treatment plan (Figure 24). One 30-degree angled implant was treatment-planned posteriorly on each side; four vertical implants were planned anteriorly. Four of the six implants were placed through extraction sockets. Once received, the surgical guide was sent to the dental laboratory for fabrication of a full-arch provisional restoration



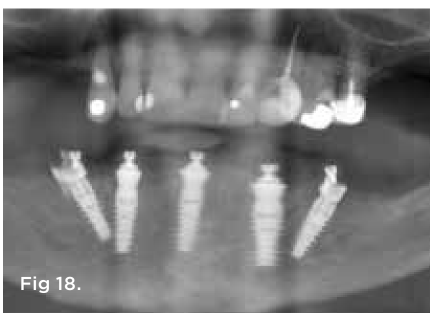


Fig 14. Minimally traumatic teeth extractions. **Fig 15.** Five implants placed, fully guided using implant mounts. **Fig 16.** Five implants in place, surgical guide removed, abutments in place. **Fig 17.** Impression and "pick-up" of open-tray impression copings. **Fig 18.** Immediate postoperative panoramic radiograph. **Fig 19.** Insertion of immediate provisional restoration, mandible.

prior to surgery. The provisional restoration was fabricated by creating a master cast using manufacturer componentry developed specifically for this application (Figure 25 and Figure 26). The master cast and an opposing arch diagnostic cast were mounted on an articulator. Using digital prosthodontic planning software and CAM milling technologies, the provisional fixed restoration was milled in one unit (Figure 27 and Figure 28).

Under intravenous sedation, the remaining maxillary teeth were removed. The surgical guide was accurately placed using a bite registration and secured with guided-surgery pins (Figure 29). Using implant-specific guided-surgery instrumentation, the six implants were placed to the planned depth and angulation. All implants were placed fully guided with implant mounts, as per guided-surgery protocols (Figure 30). Thirty-degree stock abutments were placed on the two posterior implants, and 0-degree stock abutments were placed on the four anterior implants. Titanium sleeves were placed on the abutments, and light-cured acrylic was used to accurately secure them to the presurgically fabricated provisional prosthesis. The provisional prosthesis was then secured into place using prosthetic screws (Figure 31 and Figure 32). A slight occlusal adjustment was necessary. The patient was discharged with explicit dietary and functional instructions.

Discussion

There is no CT-guided drill-guide technology with absolute precision. Stereolithographic guide deviations between virtual planning and obtained implant positions have been shown in all dimensions.[19] The highest mean deviations are found in implants placed by bone-supported guides, while implants placed by mucosa-supported guides measure lower deviations.[20] Tooth-supported drill guides measure the lowest deviations.[21] Deviations are further minimized

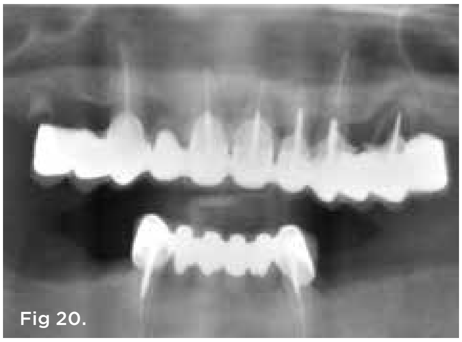
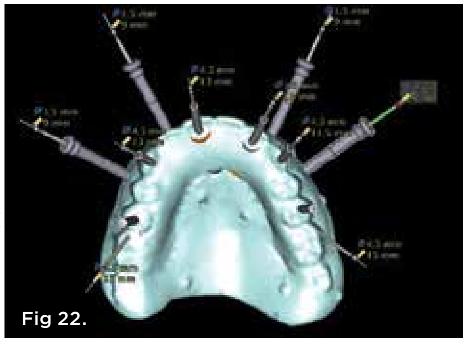


Fig 20.


Fig 21.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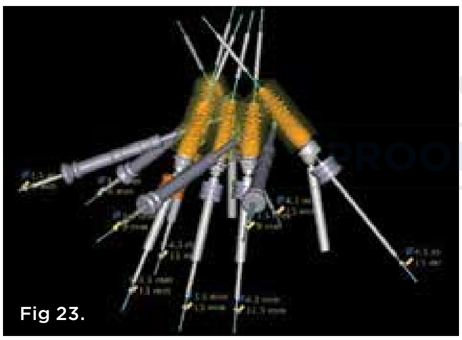
Fig 23.


Fig 24.


Fig 25.


Fig 26.


Fig 27.


Fig 28.

Fig 20. *Patient 3.* Initial evaluation, panoramic radiograph. **Fig 21.** Multiple-piece radiographic guide, full-arch extractions. **Fig 22.** Virtual treatment plan: six implants planned, abutments in place, occlusal view. **Fig 23.** Virtual treatment plan, left side. **Fig 24.** Surgical guide produced stereolithographically from treatment plan. **Fig 25.** Laboratory componentry secured in surgical guide; master cast created by pouring stone into surgical guide. **Fig 26.** Master cast created and separated. **Fig 27.** Provisional restoration milled as one unit using digital CAM technologies. **Fig 28.** Completed provisional restoration created preoperatively.

by using rigid-screw or pin fixation of a single guide, metal guide sleeves, drilling instrumentation specific to the implant to be placed, and instrumentation (implant-specific implant mounts) for the fully guided placement of implants through the surgical guide. Most systems use screws or pins to stabilize mucosal-supported guides; some systems recommend them to stabilize all guides.

Minimally invasive procedures maximize patient comfort by minimizing trauma to the tissues. Flapless dental implant insertion minimizes potential soft-tissue elevation complications such as infection, dehiscence, and soft- and hard-tissue necrosis and has been shown to have dental implant success rates equal to conventional techniques.[15,22-24] A flapless technique using surgical guidance for optimal control of drill depth and angulation minimizes potential injury to underlying anatomical structures during implant osteotomies.

Maló popularized the All-on-4 concept initially reported by Mathews.[25] The concept involves the placement of four dental implants in each arch. Two implants are typically placed in the maxillary or mandibular anterior lateral incisor/canine region in a conventional vertical fashion. Two additional anterior-posterior angled implants are placed in the posterior regions, usually in the premolar regions, at a 30-degree angulation. The posterior angled implants are placed in order to avoid the maxillary sinuses and the mental foramina, while enlarging the anterior-posterior spread of the implant platforms in order to maximize the number of teeth fabricated in the final restoration. These techniques minimized the need for preparatory bone-grafting procedures and lessened the number of implants needed for a complete-arch restoration. Manufacturers began creating stock 30-degree angled abutments specifically for this technique. The final restoration is commonly a complete-arch, which is usually limited to the second premolar or first molar teeth. As the All-on-4 concept has gained acceptance, new modifications to the technique have been developed and presented in order to alleviate the problems of severe atrophy with limited bone stock or limited interocclusal space for restorations.[26-31]

Intentional angled implant placement is not a new surgical technique, as for many years implant manufacturers have created stock angled abutments for intentional or unintentional angled implant placement. Dental laboratories have been fabricating customized abutments using traditional lab techniques almost as long as titanium root form implants have been in existence. CAD/CAM technologies are now commonly used to fabricate customized abutments in a digital environment to solve implant placement and esthetic problems.

Successful immediate and early loading of implants using the latest generation of implants has been described in the literature.[32-34] Rigid cross-arch stabilization successfully permits the immediate loading of titanium implants in an edentulous ridge, allowing rapid rehabilitation of the arch, with 6- to 24-month implant survival rates of 91% to 96.9%,[35-37] but it is dependent on proper patient


Fig 29.

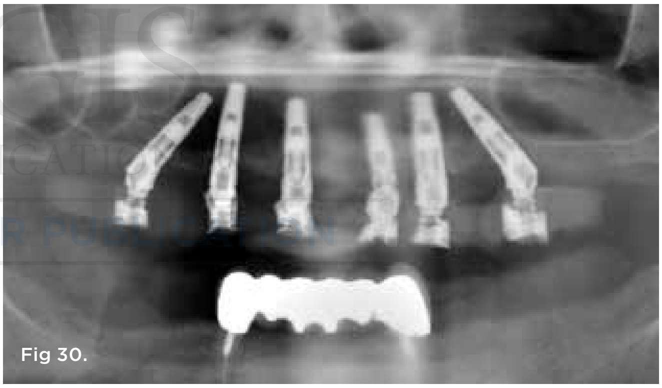
Fig 30.


Fig 31.


Fig 32.

Fig 29. Surgical guide secured in place with guided stabilization pins. Implants in place, fully guided to planned depths and angulations with implant mounts. **Fig 30.** Postoperative panoramic radiograph, immediate load with provisional restoration. **Fig 31.** Provisional restoration in place, immediately after implant surgery. **Fig 32.** Provisional restoration in place, occlusal view.

selection. New implant designs and surface technologies allow immediate placement of an implant-supported restoration following surgery as a predictable treatment option for single-tooth implants and multiple-unit fixed prostheses.[38-41] Immediate loading of dental implants has a positive effect on the tissue differentiation and bone formation around titanium implants.[42]

Implant placement followed by immediate loading is also not new. Ledermann, Schnitman, and Tarnow were among the first to introduce this technique.[38,43-45] Wolfinger presented a change in concept by placing fewer implants but loading all the implants at the same time.[46] Prior to this, immediate-loading concepts involved loading a select few implants among a larger number of dental implants in edentulous mandibles. Long-term survival rates of 96.6% to 99.4% for screw-type dental implants in edentulous mandibles using both concepts have been reported.[38,46-50] While Tarnow et al stated that immediate loading must include at least five dental implants in edentulous mandibles,[38] other authors have shown that fewer implants can be used for immediate loading.[25,41,46,51-52] This is comparable to other reports of immediate loading on dental implants, such as the 98.2% cumulative survival rate after 6 months reported by Maló,[25] the cumulative survival rate of 96% (mean follow-up, 36 months) presented by Valente,[53] and a systematic review of the Cochrane database regarding different times for loading of implants presented in 2009, in which there were no statistically significant differences in the meta-analyses for the loading of osseointegrated implants in any treatment timeframe, ie, immediate (within 1 week), early (between 1 week and 2 months), and conventional (after 2 months).[54]

Although the success rates of immediately loaded implants in the edentulous jaw is comparable to a staged healing protocol, screw loosening, prosthesis breakage, overloading, and/or parafunction can all lead to implant micromovement, resulting in potential failure.[55] Hence, proper case selection and patient awareness, education, and compliance are all critical factors for success.

Conclusion

The use of CT-guided surgery to perform the All-on-4 procedure is a combination of technologies that is in the early stages of common practice. However, early experience suggests a successful “marriage” of these two techniques, with the possibility of improved patient outcomes. Future research is required to fully examine the limitations of both technologies in the myriad situations found in the terminal dentition or atrophic jaw.

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