

Application and Success of Two Stereolithographic Surgical Guide Systems for Implant Placement with Immediate Loading

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Purpose: Two different stereolithographic surgical guide systems, NobelGuide (Nobel Biocare) and SimPlant (Materialise), were compared clinically, and the survival rates of the planned immediately loaded dental implants with prefabricated provisional restorations were evaluated. **Materials and Methods:** Patients were treated with implants using either the Materialise SimPlant system or the Nobel Biocare system. All implants were planned on cone beam computed tomography (CBCT) or CT-derived images. Mucosa-, bone-, or tooth-supported stereolithographic guides were produced using the two commercial systems. A provisional was placed immediately after implant insertion in all cases. **Results:** Fourteen patients were enrolled. Seventy-five implants were placed (34 with Materialise, 41 with Nobel Biocare) using stereolithographic surgical guides. All but one implant were loaded immediately with prefabricated provisionals. In all cases, implants were in place for a minimum of 12 months. No complications related to associated anatomy occurred. One implant failed, leading to a combined cumulative survival rate of 98.7%. There were no other intraoperative or postoperative complications. Implants placed by bone-supported guides had increased patient symptoms of postoperative swelling and discomfort. All provisionals were successful. **Conclusions:** Both types of stereolithographic surgical templates were sufficiently accurate in transferring the planned implant positions to the surgical field, allowing the placement of prefabricated provisionals. These technologies are most beneficial in patients in whom the simultaneous placement of multiple implants in combination with complex restorations is planned. *INT J ORAL MAXILLOFAC IMPLANTS* 2012;27:634–643.

Key words: guided surgery, stereolithography, surgical template, computed tomography, implant, immediate loading

Successful immediate and early loading of implants has been described in multiple studies using the latest generation of implants.^{1–3} Rigid cross-arch stabilization has been shown to successfully allow the immediate loading of titanium implants in an edentulous ridge, permitting rapid rehabilitation of the arch, with 6- to 24-month implant survival rates of 91% to 96.9%,^{4–6}

although these high survival rates are dependent on proper patient selection. With the combination of new implant designs and surface technologies, immediate placement of an implant-supported restoration following surgery is now a predictable treatment option for single-tooth implants and multiple-unit fixed prostheses.^{7–10} Immediate loading of dental implants has a positive effect on tissue differentiation and bone formation around titanium implants.¹¹

The fabrication of a provisional prosthesis immediately following surgical implant placement can be difficult and costly to the restorative dentist because of the extended chair time and patient discomfort. Numerous techniques for the fabrication of provisionals are commonly used for immediate loading. One common method used is the retrofitting of an existing complete denture. Relief is provided in the areas of the implants, and acrylic resin is used to create a retentive framework; this technique is known as a conversion prosthesis.¹² Another technique involves the processing of a laboratory-fabricated provisional following placement

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of the implants by making a traditional impression of the implants. A new approach has recently been introduced that involves the fabrication of a provisional based on a virtual implant treatment plan prior to surgery. The insertion of a prefabricated provisional at the time of implant placement allows a dramatic reduction in chair time, together with an improvement in function and esthetics. What is necessary for this technique is the use of computed tomography (CT)-guided surgery, which is designed to transfer the preoperative implant plan to the intraoperative site with precision. The prefabricated provisional can then be accurately placed.

Computerized implant planning on three-dimensional (3D) tomographic data (via CT or cone beam CT [CBCT]) followed by image-guided surgery has recently been introduced to improve the accuracy of prosthodontically driven implant positioning, thus minimizing the risk of damage to anatomic structures and allowing the full use of available bone for maximum implant stability.^{13,14} After CT-based evaluation of an implant site,¹⁵ planning of dental implant positions is performed virtually on the computer screen. The virtual treatment planning can then be transferred to the patient via insertion of implants using a surgical template,¹⁶ computer-assisted navigation,¹⁷ or a combination of both methods.¹⁸ Guided surgery with templates has been reported to increase the precision of implant placement and is suitable for transferring 3D implant plans into the clinical situation.^{19–21}

This report discusses the use of stereolithographic surgical guides in implant dentistry. Two different systems, SimPlant (Materialise) and NobelGuide (Nobel Biocare), were used clinically for implant placement with immediate loading. The hypothesis of this study was that it is possible to prefabricate prosthetic components for a provisional restoration, perform implant placement and provisionalization in one appointment with immediate function, and achieve a survival rate equivalent to what has been reported for other implant procedures for similar indications.

PATIENTS AND METHODS

All patients had partially or completely edentulous mandibles or maxillae and required adequate bone height (> 15 mm) and width (> 6 mm) to be included in the study.

SimPlant Protocol

Presurgical Preparation. Full-arch impressions were made in both arches, and casts were poured and mounted using a rigid polyvinyl siloxane interocclusal bite registration in the patient's centric position.

A radiopaque barium provisional, which reproduced the ideal positions of the planned teeth, along with an interocclusal record, was then fabricated on the mounted casts. A high-resolution multislice CT scan (MX 8000, Philips Medical) of the maxilla or mandible was generated while the patients wore the radiopaque provisional denture (scan prosthesis). The SimPlant (Materialise) planning program was used by the clinicians to evaluate the bone in relation to the positions of the planned teeth. Soft tissue thickness was estimated by evaluating the distance between the scan prosthesis and the bone crest on the images. The positions, angulations, lengths, and diameters of the dental implants were then selected digitally and placed virtually utilizing the software (Fig 1a).²² The implant placement data were transferred to the software manufacturer for fabrication of a stereolithographic model and a surgical guide (Fig 1b).²³ When a tooth-supported surgical guide was used, an optical scan of a cast of the appropriate arch was performed and was digitally superimposed on the CT scan by the manufacturer.

The surgical guide provided the exact positions of the future implants. The dental laboratory used these positions to fabricate a provisional prior to implant placement (Fig 1c). The esthetics and phonetics of the provisional were dictated by the ideal position and anatomy of the scan prosthesis. The choice of appropriate abutments and galvanic caps, used as copings and fixed into the provisional, was made by the dental technician.

Surgical Procedures. All patients were treated using local anesthesia. Depending on the patient, the surgical guide was supported by tooth, mucosa, or bone. Implant bed preparation was accomplished using standard guided surgery instrumentation and protocols according to preplanned drilling depth data. The surgical guide was then removed and insertion of implants was accomplished with a standard torque wrench under direct visualization. Primary stability of the implants was tested with the Periotest device (Medizintechnik Gulden), and abutments (Dentsply Friadent GmbH) were then placed on the implants. A panoramic radiograph was taken immediately after the procedure.

Prosthetic Protocol. If a fixed restoration was planned, Standard or Balanced abutments (Dentsply Friadent GmbH) were placed and torqued to 15 to 25 Ncm at the time of implant surgery. Ankylos caps (Dentsply Friadent GmbH) or galvano copings were mounted onto the abutments and incorporated into the provisional using cold-curing acrylic resin (Fig 1d). The galvano caps were glued into the restorations while in the patient's mouth, reducing potential complications by improving the precision of fit.²⁴ The acrylic resin or metal-reinforced provisional was cemented

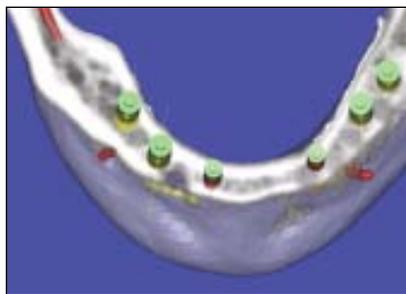


Fig 1a Materialise treatment plan for an edentulous mandible that will receive six implants.



Fig 1b Materialise surgical guides and stereolithographic mandible fabricated from the virtual treatment plan.



Fig 1c Laboratory metal-reinforced provisional.



Fig 1d (left) Galvanic caps are secured in the provisional.



Fig 1e (right) Occlusion of the provisional after implant insertion.

into position and left in passive occlusion during healing. If a removable prosthesis was planned, the existing denture was modified into an implant-supported removable prosthesis and delivered to the patient. Occlusal adjustments were made as needed (Fig 1e).

After 2 weeks, the patients were evaluated clinically and instructed to progressively increase masticatory loads until a normal pattern was reached at 6 weeks postoperative. After 6 weeks to 3 months of uneventful healing, the provisional was removed, implant stability was assessed, and the definitive restorations were cemented. Maximal occlusal contact in centric occlusion was established to distribute loads equally among adjacent teeth and the prosthesis. Lateral contacts were eliminated by evaluating points of contact.

Postoperative Follow-up. Analgesics (acetaminophen) and 0.2% chlorhexidine rinse were administered for 3 to 5 days postoperatively; 2 weeks of a soft diet was recommended. The patients were seen 1 day, 1 and 2 weeks, and 1, 3, and 12 months after surgery. Panoramic radiographs were taken after implant placement, after 3 months (before placement of the definitive restoration), and after 12 months. Implant survival was based on clinical stability and comfortable patient mastication and esthetics. Additionally, the criteria for success (absence of infection, peri-implant disease, or radiolucency around the implants) of Albrektsson et al²⁵ were used.

NobelGuide Protocol

Presurgical Preparation. Pretreatment casts were made and mounted on an articulator. A diagnostic wax-up was made to represent the anatomy and ideal locations of the planned implants. A radiographic guide (Fig 2a) with a radiographic index (rigid polyvinyl siloxane interocclusal bite registration) was made at the patient's appropriate centric position. The patients wore the radiographic guide and index during a medical-grade multislice CT scan of the appropriate jaw, followed by a second scan of the radiographic guide alone. The CT data were then imported into the NobelGuide software and converted for treatment planning. Virtual treatment planning of dental implants according to the locations of the planned restorations and the patient's individual anatomy was then performed (Fig 2b). Once completed, the planning data were sent to the manufacturer via the Internet for fabrication of the stereolithographic surgical template (the NobelGuide) to be used at the time of surgery (Fig 2c).

Prior to implant placement, the surgical templates were sent to a dental laboratory. Using the NobelGuide laboratory components and the techniques designed for the preoperative fabrication of provisionals, the implant and abutment replicas, gingival mask, and guided anchor pins were placed into the surgical template. Stone was then poured into the tissue side of the surgi-



Fig 2a Radiographic guide. Note the use of gutta-percha points as fiducial markers.

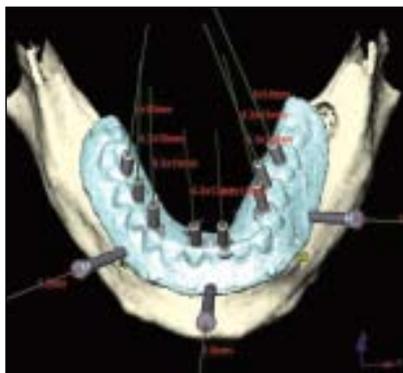


Fig 2b NobelGuide treatment plan; eight implants are planned.



Fig 2c The surgical template (the NobelGuide), fabricated from the virtual treatment plan.



Fig 2d The master cast, fabricated from the surgical template.



Fig 2e Laboratory metal-reinforced framework.



Fig 2f Laboratory-fabricated provisional.



Fig 2g The surgical template is in place and the implants are in place using implant mounts.



Fig 2h Implants in place with QuickTemp abutments attached. Note the anterior incision that has been closed after a small crestal alveoplasty.



Fig 2i Occlusal view of provisional after implant insertion.

cal template, creating a master cast (Fig 2d). If the patient was partially edentulous, an impression was first made; then a cast was poured of the arch to receive implants, the surgical template was fitted to the cast, the areas to receive implants were cut out of the stone cast, and the master cast was created as described using the appropriate implant analogs. Using a bite registration, the master cast was mounted on an articulator. In completely edentulous patients, the master cast was placed and fit to the radiographic guide for mounting with a bite registration. The surgical tem-

plates were then placed and secured to the master cast with guided anchor pins. A polyvinyl siloxane material was then used to create a surgical index between the surgical template and the opposing arch. This index was used at the time of surgery to ensure correct positioning of the surgical template prior to securing it at the time of implant placement. Using the mounted master cast, the dental technician placed stock or customized abutments and fabricated metal-reinforced acrylic resin provisionals that would be placed at the time of implant insertion (Figs 2e and 2f). Different

types of abutments were used depending on the patient. In most cases, on the articulator, an interocclusal bite registration was made between the provisionals and the opposing arch to transfer the positioning, centric relation, and occlusal vertical dimension information to the patient at the time of provisional insertion.

Surgical Procedures. All patients were treated under intravenous sedation with local anesthesia. A mucosa-supported surgical guide was used for edentulous patients. In partially edentulous cases, all surgical guides were tooth-supported. Unless limited attached gingiva was present and its preservation was important, or a small amount of bone had to be removed, all implants were placed with a flapless technique. Following the NobelGuide surgical protocol, the surgical templates were placed and secured using the surgical index and guided anchor pins. Osteotomies were accomplished using the NobelGuide surgical instrumentation and drilling protocol. All implants were placed with complete guidance, with the implants secured to implant mounts to ensure accuracy of the planned implant depths and directions (Fig 2g). After the implants were inserted, the NobelGuide was removed and the insertion torque of all implants was checked using a manual torque wrench. A panoramic radiograph was obtained immediately after the procedure. All patients received appropriate antibiotics and analgesics postoperatively for 1 week.

Prosthetic Protocol. Three types of abutments were used: QuickTemp immediate load abutments, guided abutments, and customized titanium sleeve abutments (Fig 2h). All patients received prefabricated metal-reinforced provisionals (Fig 2i). All abutments were placed with finger pressure rather than torqued. In the QuickTemp abutment cases, standard white nylon sleeves were placed on the abutments, and cold-curing acrylic resin was added to the provisional to "pick up" the positions of the nylon sleeves. Additional cold- or light-curing acrylic resin was then added to contour the provisional appropriately. The provisionals were then temporarily cemented into position. Minor occlusal adjustments were performed as necessary.

A soft diet was recommended for a minimum of 2 weeks, and patients did not resume a normal diet until 10 weeks after surgery. After 3 months of uneventful healing, the provisionals were removed and implant stability was evaluated by clinical examination of the implants, patient symptoms when removing abutments, and serial radiographic examinations. Appropriate implant-level impressions were then taken and the definitive abutments and restorations were fabricated and cemented. Maximal occlusal contact in centric occlusion was established with equal load distribution between adjacent teeth and the prosthesis. Lateral contacts were eliminated by evaluating points of contact.

Postoperative Follow-up. The patients were seen 1 day, 1 week, and 1, 3, and 12 months after surgery. Panoramic or periapical radiographs were obtained after implant placement, after 3 months of healing (before beginning fabrication of the definitive restorations), after the definitive restorations were fabricated, and after 12 months. Implant survival was based on clinical implant stability, patient comfort, and absence of infection, peri-implant disease, and radiolucency around the implant according to Albrektsson et al.²⁵

RESULTS

Fourteen patients participated in the study and received a total of 75 implants. All implants were placed in healed areas with adequate bone volume.

Eight consecutive patients (six men and two women; mean age, 59.2 years; range, 51 to 77 years) with four completely and four partially edentulous mandibles or maxillae were treated with the SimPlant protocol. Thirty-four Ankylos implants (Dentsply Friadent) were placed to support four removable and four fixed restorations. All patients had their implants in place for a minimum of 12 months. With Periotest values ranging from -7 to -1 , 33 implants were able to be immediately loaded after Periotest and manual torque wrench evaluations. All implants were stable and successful in function at all visits, rendering a 100% survival rate. All 34 implants were successfully included in the definitive restorations. One implant was not loaded immediately after surgery because the bone density was so low that sufficient primary stability could not be achieved.

Six patients (two men and four women; mean age 60.1 years; range, 56 to 66 years) with three completely and three partially edentulous mandibles or maxillae were treated with the Nobel Biocare protocol. Forty-one Nobel Biocare implants (30 NobelReplace Tapered, 8 Brånemark, 3 NobelActive) were placed. Twenty-five implants received QuickTemp immediate load abutments, eight implants received guided abutments, and eight implants received customized titanium sleeve abutments. All patients received fixed provisionals, five of which were cemented. One patient, a fully edentulous guided abutment case, received a prefabricated provisional that was screw retained, per the guided abutment protocol. All patients had their implants in place for a minimum of 12 months. All implants were placed with an insertion torque of 35 to 45 Ncm. All implants were immediately loaded with prefabricated metal-reinforced provisionals. One implant failed in the left canine/premolar region of a completely edentulous mandible that had received eight implants and guided abutments to secure the provisional. Failure of this implant was radiographically evident 3 months

Table 1 Implants and Restorations Placed with Guided Surgery

Patient no.	Implant data			
	Type	No.	Positions*	Restoration
1	Ankylos	6	16, 15, 13, 23, 25, 26	RPD
2	Ankylos	4	15, 14, 24, 25	Removable prosthesis
3	Ankylos	2	24, 25	Fixed crowns
4	Ankylos	5	16, 15, 14, 11, 21	FPD
5	Ankylos	8	37, 36, 35, 33, 43, 45, 46, 47	RPD
6	Ankylos	2	34, 36	Fixed crowns
7	Ankylos	3	34, 35, 36	Fixed crowns
8	Ankylos	4	13, 11, 21, 23	Removable prosthesis
9	Nobel Brånemark	8	45, 44, 43, 42, 32, 33, 34, 35	FPD
10	Nobel Replace tapered	8	46, 45, 43, 41, 31, 34, 35, 36	FPD
11	Nobel Replace tapered	5	47, 46, 35, 36, 37	FPD
12	Nobel Replace tapered	11	17, 16, 15, 14, 13, 12, 23, 24, 25, 26, 27	FPD
13	NobelActive	3	12, 21, 22	FPD
14	Nobel Replace tapered	6	46, 45, 44, 34, 35, 36	FPD

*FDI tooth-numbering system used.

FPD = fixed partial denture; RPD = removable partial denture.

after implant insertion, prior to fabrication of the definitive restoration. The implant was easily removed and not replaced. The full-arch definitive restoration was then fabricated and inserted without complication. The cumulative survival rate of the NobelGuide-inserted implants was 97.6% (Table 1).

In all, using CT-guided technologies, 75 implants were planned and placed in 14 patients (7 completely edentulous and 7 partially edentulous). All but one implant were immediately loaded with provisional restorations. In all cases, implants had remained in place for a minimum of 12 months. One implant failed, leading to a combined cumulative survival rate of 98.7%. There were no other intraoperative or postoperative complications in any of the 14 patients. All patients went on to successful fabrication and insertion of definitive restorations.

DISCUSSION

The results support the research hypothesis that it is possible to prefabricate prosthetic components for a provisional, perform the treatment in one appointment with immediate function, and achieve a survival rate equivalent to what is reported for other implant procedures for the same indication. The reader should note that, although two different CT-guided software pro-

grams, radiographic and planning protocols, implant and abutment systems, instrumentation and drilling protocols, and processes for the fabrication and insertion of provisionals were used in this study, the results were essentially the same. Within the limited number of observed patients, two safe and predictable protocols were defined. It is also important to note that, based on the assessment of both the clinicians and the patients, the esthetic and functional outcomes of both therapies were high. Soft tissue healing and adaptation to the abutments and provisional crowns resulted in harmonious gingival anatomy. Although this study shows excellent results, it is important to emphasize that the clinical outcomes may be dependent on good patient selection, pretreatment planning, and diagnostic procedures.

Both stereolithographic surgical templates were sufficiently accurate in transferring the planned implant positions to the surgical field. CT-guided procedures with surgical guides are known to enhance safety in dental implant placement compared to the “free hand” technique^{26,27} while being compatible with all aspects of implant surgery, including flapless techniques.¹⁸ According to the NobelGuide protocol, when using the guided abutment, the accuracy should be sufficient for placing a completely prefabricated definitive restoration. At this time, no CT-guided surgical template technology is available that features absolute precision.

All articles written on stereolithographic guides have observed deviations between virtual and actual implant positions in all dimensions.²⁸ According to the literature, implants that are placed with the assistance of bone-supported guides have the largest mean deviations, whereas smaller deviations have been measured for implants that are placed with mucosa-supported guides.²⁹ The smallest deviations have been seen with tooth-supported guides.³⁰ Rigid screw or pin fixation of a single guide, incorporating metal sleeves and specific drilling instrumentation, further minimizes errors. Most systems use these techniques to stabilize mucosa-supported guides; NobelGuide uses this concept to stabilize all guides.

The primary advantage of placing a definitive restoration immediately after implant insertion is a reduction in treatment time. Most clinicians using these technologies are placing prefabricated provisionals after implant insertion for many reasons. If a definitive restoration is planned, the dental technician has no idea what the anatomy and contour of the healed gingiva will be, regardless of whether the surgery is done flapless or not. The experience gained from the observation of the provisional restoration and gingival healing may aid the dentist in providing the patient with the desired contour and esthetics. Additionally, although the success of implants placed with and without a guide is very high, failures do occur on occasion. Evidence of most failures related to the surgical placement of an implant usually occurs within the first 3 to 4 months of placement. A failure is best diagnosed prior to the placement of a definitive restoration. In this study, only prefabricated provisionals were placed. According to Abrahamsson et al, the shift from a healing abutment to a permanent abutment resulted in the establishment of a transmucosal attachment, the dimension and quality of which did not differ from those of the mucosal barrier formed around a permanent abutment placed after surgery.³¹ Finally, a composite resin restoration or an acrylic resin occlusal surface has been found to reduce the impact forces and has better shock-absorbing behavior than ceramic, thus reducing the occlusal forces placed on a newly inserted implant.³²

Clinically, since the NobelGuide system is more comprehensive than the SimPlant system, it is easier to use overall. The NobelGuide system is designed for the planning and placement of implants with complete guidance in accurate positions, depths, and angulations, allowing for immediate loading of implants if desired. Instrumentation is available for the fully guided placement of all Nobel Biocare implants. The NobelGuide technology and instrumentation can be used, for depth and direction, in performing osteotomies for a cylindrical implant of any implant system. How-

ever, cylindrical implants cannot be accurately placed through the guide, because the NobelGuide implant mounts are designed only for Nobel Biocare implants. In these cases, implant placement to depth should be determined with the guide off, usually after an incision and elevation of a tissue flap. SimPlant is designed as an open system for use with all implant systems. Although this feature increases its functionality, it is also a limitation, because it is not perfectly adapted to one implant system. Several implant manufacturers have created instrumentation specific for the placement of their cylindrical implants, flapless and to depth, using the SimPlant system (eg, Facilitate, AstraTech Dental; ExpertEase, Dentsply Friadent; Navigator, Biomet/3i). Other nonstereolithographic model technologies are available for the fabrication of surgical guides as well (eg, iDent; EZ Guide, Keystone Dental; coDiagnostiX, Straumann). These technologies fabricate a surgical guide by milling the radiographic prosthesis according to a digital CT-based treatment plan. Guide sleeves are then added to the guide to direct the depth and direction of osteotomies prior to implant placement.

Minimally invasive procedures are designed to maximize patient comfort by reducing traumatic injury to the tissues. Flapless insertion of dental implants lessens the potential for complications arising from soft tissue elevation such as infection, dehiscence, and soft and hard tissue necrosis and provides dental implant success rates that are equal to those achieved using conventional techniques.³³⁻³⁵ A flapless technique that uses surgical guidance for optimal control of drill depth and angulation minimizes the potential injury to underlying anatomical structures during preparation of the implant osteotomy. In the present series, in the SimPlant cases, since fully guided instrumentation for implant insertion was not available for the Ankylos implant system, flapless surgery could not be performed in these patients. Depth and angulation guidance of all osteotomies was possible, but implant placement required direct visualization of the bone, requiring an incision and flap elevation.

Immediate loading of dental implants after implant placement is not a new strategy. Ledermann, Schnitman and coworkers, and Tarnow et al were among the pioneers of this technique.^{7,36-38} A change in concept was introduced by Wolfinger et al, who placed fewer implants but loaded them all at the same time.³⁹ Prior to this, immediate loading concepts involved loading a select few implants among a larger number of dental implants in edentulous mandibles. Both concepts for immediate loading have been reported to achieve long-term survival rates of 96.6% to 99.4% for screw-type dental implants in edentulous mandibles.³⁹⁻⁴³ While Tarnow et al stated that immediate loading must include at least five dental implants in edentu-

lous mandibles,⁷ other authors have shown that fewer implants can be used for immediate loading.^{10,39,44–46}

In this study, the decision of whether to load an implant immediately was made clinically, based on manual sensation and a minimum torque insertion value (Ncm) and/or a minimum Periotest value. A high degree of primary implant stability (high value of insertion torque) seems to be one of the prerequisites for successful immediate or early loading.⁴⁷ Insertion torques ranging from 25 to 50 Ncm appeared to be an effective criterion for good primary stability and possible immediate loading. Periotest measurements can be an effective indicator of the possibility of immediate loading when used in combination with the previously mentioned means of evaluating the inserted implant.

In the present series, a combined 98.7% cumulative implant survival rate was achieved after 1 year for immediately loaded implants. This is comparable to other reports of immediate loading of dental implants, such as the 98.2% cumulative survival rate after 6 months reported by Malo et al,⁴⁶ the cumulative survival rate of 96% (mean follow-up, 36 months) presented by Valente et al,⁴⁸ or the results from a systematic review of the Cochrane database regarding different times for loading of implants presented in 2009.⁴⁷ There were no statistically significant differences in the meta-analysis of Esposito et al for the loading of osseointegrated implants in any treatment time frame, ie, immediate (within 1 week), early (between 1 week and 2 months), and conventional (after 2 months).⁴⁷

Although the success rates of immediately loaded implants in the edentulous jaw are comparable to those seen with a staged healing protocol, there are greater risks with this approach. Screw loosening, prosthesis breakage, overloading, and/or parafunction can all lead to significant micromovement of implants, resulting in potential failure.⁴⁹ Hence, proper case selection and patient awareness, education, and compliance are all critical factors for success.

When treatment planning completely edentulous cases, principles of implant spacing and cross-arch stabilization should be adhered to. Obviously, when fewer implants are used for immediate loading, these parameters become more important. CT-guided surgery allows for the accurate preoperative evaluation of a patient's anatomy and the ability to place and position implants predictably to maximize implant length, angulation, and, potentially, initial stability. Further studies are needed to confirm these hypotheses.

The technologies available today do have some limitations and questions that demand further investigation as to their effect on guided surgery outcomes. There are questions as to the resolution and accuracy of specific CBCT machines related to the "gold standard" of medical-grade CT scanners.⁵⁰ Some proprietary soft-

ware programs have a calibration object (Nobel Biocare), which calibrates the CBCT/CT machine to an acrylic resin object of a known density, thus adjusting a specific machine more precisely for the NobelGuide protocol.

To produce a stereolithographic surgical guide or model, manufacturing involves the reproduction of the digitally planned dimensions of the surgical guide or model by selectively solidifying an ultraviolet-sensitive liquid resin using a laser beam. Stereolithographic materials have inherent potential problems in their fabrication, which can lead to light sensitivity and expansion and/or shrinkage of the material over time. However, according to D'Haese et al, it is unlikely that the production process of the guide has a major impact on the total accuracy of a mucosa-supported stereolithographic guide.⁵¹ Sterilization and handling of stereolithographic materials also can present problems. High-temperature autoclaves will distort the material. From the standpoint of heat generation, studies have shown that preparing an implant site using surgical guides generates more heat than classic implant site preparation, regardless of the irrigation used.⁵²

It is important to emphasize to readers that there is a steep learning curve involved in the successful integration of CT technology and CT-guided surgery into dental implant practice. The authors strongly encourage all clinicians who are interested in these technologies to pursue continuing education on the technologies prior to clinical use. Recent literature agrees with these statements.⁵³ CT-guided implant surgery is not conventional implant surgery. Knowledge of the complete protocols, CT scans, proprietary treatment-planning software programs, and guided surgery instrumentation and techniques, in addition to good diagnosis and patient selection, are all instrumental in successful treatment outcomes. Clinicians should also be aware of the inherent additional costs involved in the use of these proprietary software programs and computer-aided design/computer-assisted manufacture technologies.

CONCLUSION

The clinical data from this study suggest that computed tomography with the use of interactive planning software and computer-aided rapid prototyping of surgical guides may provide significant benefits in the placement of dental implants while allowing the placement of prefabricated provisional restorations immediately after surgery. Even in complex cases, these technologies can provide clinicians with a prosthetic-based surgical technique that results in efficient, highly predictable, and comfortable patient treatment. Computed tomography-guided technologies with surgical

guides can be used in single- or multiple-implant cases and in both partially and fully edentulous patients. Because of the additional time and expense needed for planning and treatment using these techniques, the tendency is to use these technologies in multiple-implant and complex restorative situations. Proper patient selection and attention to guided surgery principles will increase treatment success.

REFERENCES

- Gapski R, Wang HL, Mascarenhas P, Lang NP. Critical review of immediate implant loading. *Clin Oral Implants Res* 2003;14:515–527.
- Ogawa T, Nishimura I. Different bone integration profiles of turned and acid-etched implants associated with modulated expression of extracellular matrix genes. *Int J Oral Maxillofac Implants* 2003;18:200–210.
- Zechner W, Tangl S, Furst G, et al. Osseous healing characteristics of three different implant types. *Clin Oral Implants Res* 2003;14:150–157.
- Lorenzoni M, Pertl C, Zhang K, Wegscheider WA. In-patient comparison of immediately loaded and non-loaded implants within 6 months. *Clin Oral Implants Res* 2003;14:273–279.
- Jaffin RA, Kumar A, Berman CL. Immediate loading of dental implants in the completely edentulous maxilla: A clinical report. *Int J Oral Maxillofac Implants* 2004;19:721–730.
- Gatti C, Haefliger W, Chiapasco M. Implant-retained mandibular overdentures with immediate loading: A prospective study of ITI implants. *Int J Oral Maxillofac Implants* 2000;15:383–388.
- Tarnow DP, Emthiaz S, Classi A. Immediate loading of threaded implants at stage 1 surgery in edentulous arches: Ten consecutive case reports with 1- to 5-year data. *Int J Oral Maxillofac Implants* 1997;12:319–324.
- Chatzistavrou M, Felton DA, Cooper LF. Immediate loading of dental implants in partially edentulous patients: A clinical report. *J Prosthodont* 2003;12:26–29.
- Glauser R, Lundgren AK, Gottlow J, et al. Immediate occlusal loading of Brånemark TiUnite implants placed predominantly in soft bone: 1-year results of a prospective clinical study. *Clin Implant Dent Relat Res* 2003;5(suppl 1):47–56.
- Abboud M, Koeck B, Stark H, Wahl G, Paillon R. Immediate loading of single-tooth implants in the posterior region. *Int J Oral Maxillofac Implants* 2005;20:61–68.
- Vandamme K, Naert I, Geris L, Sloten JV, Puers R, Duyck J. Histodynamics of bone tissue formation around immediately loaded cylindrical implants in the rabbit. *Clin Oral Implants Res* 2007;18:471–480.
- Zitzmann NU, Marinello CP. Treatment plan for restoring the edentulous maxilla with implant-supported restorations: Removable overdenture versus fixed partial denture design. *J Prosthet Dent* 1999;82:188–196.
- Harris D, Buser D, Dula K, et al. E.A.O. guidelines for the use of diagnostic imaging in implant dentistry. A consensus workshop organized by the European Association for Osseointegration in Trinity College Dublin. *Clin Oral Implants Res* 2002;13:566–570.
- Kopp KC, Koslow AH, Abdo OS. Predictable implant placement with a diagnostic/surgical template and advanced radiographic imaging. *J Prosthet Dent* 2003;89:611–615.
- Homolka P, Beer A, Birkfellner W, et al. Bone mineral density measurement with dental quantitative CT prior to dental implant placement in cadaver mandibles: Pilot study. *Radiology* 2002;224:247–252.
- van Steenberghe D, Naert I, Andersson M, Brajnovic I, Van Cleynenbreugel J, Suetens P. A custom template and definitive prosthesis allowing immediate implant loading in the maxilla: A clinical report. *Int J Oral Maxillofac Implants* 2002;17:663–670.
- Ewers R, Schicho K, Truppe M, et al. Computer-aided navigation in dental implantology: 7 years of clinical experience. *J Oral Maxillofac Surg* 2004;62:329–334.
- Casap N, Tarazi E, Wexler A, Sonnenfeld U, Lustmann J. Intraoperative computerized navigation for flapless implant surgery and immediate loading in the edentulous mandible. *Int J Oral Maxillofac Implants* 2005;20:92–98.
- Fortin T, Bosson JL, Coudert JL, Isidori M. Reliability of preoperative planning of an image-guided system for oral implant placement based on 3-dimensional images: An in vivo study. *Int J Oral Maxillofac Implants* 2003;18:886–893.
- Van Steenberghe D, Malevez C, Van Cleynenbreugel J, et al. Accuracy of drilling guides for transfer from three-dimensional CT-based planning to placement of zygoma implants in human cadavers. *Clin Oral Implants Res* 2003;14:131–136.
- Esposito M, Grusovin MG, Willings M, Coulthard P, Worthington HV. The effectiveness of immediate, early, and conventional loading of dental implants: A Cochrane systematic review of randomized controlled clinical trials. *Int J Oral Maxillofac Implants* 2007;22:893–904.
- Verstreken K, Van Cleynenbreugel J, Marchal G, Naert I, Suetens P, van Steenberghe D. Computer-assisted planning of oral implant surgery: A three-dimensional approach. *Int J Oral Maxillofac Implants* 1996;11:806–810.
- Parel SM, Funk JJ. The use and fabrication of a self-retaining surgical guide for controlled implant placement: A technical note. *Int J Oral Maxillofac Implants* 1991;6:207–210.
- Zafropoulos GG, Rebbe J, Thielen U, Deli G, Beaumont C, Hoffmann O, Beaumont C. Zirconia removable telescopic dentures retained on teeth or implants for maxilla rehabilitation. Three-year observation of three cases. *J Oral Implantol* 2010;36:455–465. Epub 2010 Jun 14.
- Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1986;1:11–25.
- Komiyama A, Pettersson A, Hultin M, Nasstrom K, Klinge B. Virtually planned and template-guided implant surgery: An experimental model matching approach. *Clin Oral Implants Res* 2011 Mar;22(3):308–313. Epub 2010 Sep 7.
- Wagner A, Wanschitz F, Birkfellner W, et al. Computer-aided placement of endosseous oral implants in patients after ablative tumour surgery: Assessment of accuracy. *Clin Oral Implants Res* 2003;14:340–348.
- D'Haese J, Van De Velde T, Komiyama A, Hultin M, De Bruyn H. Accuracy and complications using computer-designed stereolithographic surgical guides for oral rehabilitation by means of dental implants: A review of the literature. *Clin Implant Dent Relat Res* 2010 May 11 [Epub ahead of print].
- Arisan V, Karabuda ZC, Ozdemir T. Accuracy of two stereolithographic guide systems for computer-aided implant placement: A computed tomography-based clinical comparative study. *J Periodontol* 2010;81:43–51.
- Ozan O, Turkyilmaz I, Ersoy AE, McGlumphy EA, Rosenstiel SF. Clinical accuracy of 3 different types of computed tomography-derived stereolithographic surgical guides in implant placement. *J Oral Maxillofac Surg* 2009;67:394–401.
- Abrahamsson I, Berglundh T, Sekino S, Lindhe J. Tissue reactions to abutment shift: An experimental study in dogs. *Clin Implant Dent Relat Res* 2003;5:82–88.
- Gracis SE, Nicholls JL, Chalupnik JD, Yuodelis RA. Shock-absorbing behavior of five restorative materials used on implants. *Int J Prosthodont* 1991;4:282–291.
- Arisan V, Karabuda CZ, Ozdemir T. Implant surgery using bone- and mucosa-supported stereolithographic guides in totally edentulous jaws: Surgical and post-operative outcomes of computer-aided vs. standard techniques. *Clin Oral Implants Res* 2010;21:980–988.
- Becker W, Goldstein M, Becker BE, Sennerby L. Minimally invasive flapless implant surgery: A prospective multicenter study. *Clin Implant Dent Relat Res* 2005;7(suppl 1):S21–27.
- Cannizzaro G, Torchio C, Leone M, Esposito M. Immediate versus early loading of flapless-placed implants supporting maxillary full-arch prostheses: A randomised controlled clinical trial. *Eur J Oral Implantol* 2008;1:127–139.
- Ledermann D. 6-year clinical trial with titanium plasma-coated ITI (Internationales Team für Implantologie) screw implants in the mandibular interforaminal region. *SSO Schweiz Monatsschr Zahnheilkd* 1983;93:1070–1089.

37. Ledermann P. Bar-prosthetic management of the edentulous mandible by means of plasma-coated implantation with titanium screws. *Dtsch Zahnärztl Z* 1979;34:907–911.
38. Schnitman PA, Wohrle PS, Rubenstein JE, DaSilva JD, Wang NH. Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. *Int J Oral Maxillofac Implants* 1997;12:495–503.
39. Wolfinger GJ, Balshi TJ, Rangert B. Immediate functional loading of Brånemark System implants in edentulous mandibles: Clinical report of the results of developmental and simplified protocols. *Int J Oral Maxillofac Implants* 2003;18:250–257.
40. Horiuchi K, Uchida H, Yamamoto K, Sugimura M. Immediate loading of Brånemark system implants following placement in edentulous patients: A clinical report. *Int J Oral Maxillofac Implants* 2000;15:824–830.
41. Ganeles J, Rosenberg MM, Holt RL, Reichman LH. Immediate loading of implants with fixed restorations in the completely edentulous mandible: Report of 27 patients from a private practice. *Int J Oral Maxillofac Implants* 2001;16:418–426.
42. Aalam AA, Nowzari H, Krivitsky A. Functional restoration of implants on the day of surgical placement in the fully edentulous mandible: A case series. *Clin Implant Dent Relat Res* 2005;7:10–16.
43. Degidi M, Piattelli A, Felice P, Carinci F. Immediate functional loading of edentulous maxilla: A 5-year retrospective study of 388 titanium implants. *J Periodontol* 2005;76:1016–1024.
44. Brånemark PI, Engstrand P, Öhrnell LO, et al. Brånemark Novum: A new treatment concept for rehabilitation of the edentulous mandible. Preliminary results from a prospective clinical follow-up study. *Clin Implant Dent Relat Res* 1999;1:2–16.
45. De Bruyn H, Kisch J, Collaert B, Linden U, Nilner K, Dvarsater L. Fixed mandibular restorations on three early-loaded regular platform Brånemark implants. *Clin Implant Dent Relat Res* 2001;3:176–184.
46. Malo P, Rangert B, Nobre M. “All-on-Four” immediate-function concept with Brånemark System implants for completely edentulous mandibles: A retrospective clinical study. *Clin Implant Dent Relat Res* 2003;5(suppl 1):2–9.
47. Esposito M, Grusovin MG, Achille H, Coulthard P, Worthington HV. Interventions for replacing missing teeth: Different times for loading dental implants. *Cochrane Database Syst Rev* 2009:CD003878.
48. Valente F, Schirolli G, Sbrenna A. Accuracy of computer-aided oral implant surgery: A clinical and radiographic study. *Int J Oral Maxillofac Implants* 2009;24:234–242.
49. Misch CM. Immediate loading of definitive implants in the edentulous mandible using a fixed provisional prosthesis: The denture conversion technique. *J Oral Maxillofac Surg* 2004;62:106–115.
50. Van Assche N, van Steenberghe D, Guerrero ME, et al. Accuracy of implant placement based on pre-surgical planning of three-dimensional cone-beam images: A pilot study. *J Clin Periodontol* 2007;34:816–821.
51. D’Haese J, Van De Velde T, Elaut L, De Bruyn H. A prospective study on the accuracy of mucosally supported stereolithographic surgical guides in fully edentulous maxillae. *Clin Implant Dent Relat Res* 2009 Nov 10 [Epub ahead of print].
52. Misir AF, Sumer M, Yenisey M, Ergioglu E. Effect of surgical drill guide on heat generated from implant drilling. *J Oral Maxillofac Surg* 2009;67:2663–2668.
53. Puig CP. A retrospective study of edentulous patients rehabilitated according to the “All-on-Four” or the “All-on-Six” immediate function concept using flapless computer-guided implant surgery. *Eur J Oral Implantol* 2010;3:155–163.