Computer-guided implant surgery and immediate provisionalization by chair-side CAD-CAM: A case report

This report demonstrates a method of generating a chair-side and computer-aided template for implant surgery based on the Top-Down and restoration-driven concept. Compared to the traditional CAD-CAM process which requires multiple steps to be taken between dental clinic and laboratory, this alternative procedure, VARO guide system (VARO Guide, CAD, Pre-Guide, VARO-mill, NeoBiotech, Seoul, South Korea) enables accurate and patient-friendly implant surgery as well as immediate provisional restoration in a single visit. First, bite-registration at centric jaw relation and CBCT were taken using the Pre-Guide. The CBCT data was then reorganized directly through the chair-side CAD, and we could determine the most appropriate 3-dimensional position of implant. The STL file was extracted and put into the chair-side CAM (VARO-mill) to fabricate a VARO. This surgical guide allowed the implants to be accurately positioned into the planned sites within an hour. (J Korean Acad Prosthodont 2021;59:478-86)

Keywords
CAD-CAM; Chair-side immediate restoration; Patient-friendly; Pre-Guide; Top-Down; Restoration-driven; VARO Guide

Introduction

Through the incorporation of digital technology, the ideal location of implant is determined based on an imaginary final prosthetic restoration which is designed in CAD, thereby minimalizing errors during implant surgery and the following prosthetic treatment. One of the most significant contribution is the development
Immediate loading of single-implant crowns are limited to situations where primary implant stability of insertion torque is in the range of 30 to 55 Ncm, and when systematic or local contraindications like parafunctional activities or large bone defects are absent.\textsuperscript{3}

This case report focuses on the successful restoration of bilateral molars through utilizing 1-visit guided implant surgery and immediate loading so that the patient could chew food conveniently following the patient-friendly implant surgery.

**Case Report**

A 74-year-old female patient visited our department (Biomaterials & Prosthodontics, Kyung Hee University dental hospital at Gangdong, Seoul, Korea) with a chief complaint of poor masticatory performance due to the loss of several molars and ill-fitting mandibular removable partial denture. A patient had medical history of osteoporosis and had been injected Prolia accordingly. #27, #36, #37, #46, and #47 (FDI numbering system) were missing. Maxillary left premolar (#25) showed crown fracture with secondary caries, and maxillary left molar (#26) showed severe attrition and a crack line. Mandibular premolars (#34, #35, #44, #45) that have been previously restored with surveyed crowns showed buccal

of precise surgical guide that allows implants to be accurately placed in the pre-arranged position 3-dimensionally. Although the process of surgical guide fabrication have continuously been simplified, it still involves impression taking (or intraoral scan), template fabrication for CT scans, and the final step of 3D-printing the surgical guide.

In order to eliminate some of the inconveniences involving the conventional computer-guide production method such as working between dentist’s office and dental laboratory, this study introduces VARO Guide (Neobiotech, Seoul, Korea) as an example aimed to provide 1-day restoration under the Top-Down and restoration-driven concept.\textsuperscript{1,2}

A pre-made resin tray so called ‘Pre-Guide (VARO Guide; Neobiotech, Seoul, Korea)’ is adjusted on the operation site and used to take CT images. Computer-aided design is then performed on the chair-side computer, and the VARO Guide is manufactured within an hour at the clinic. To put in more detail, pre-fabricated Pre-Guide tray containing photopolymer resin is placed on the surgical site at CR position, photo-polymerized intraorally, and CT image is taken. The CT data is reproduced directly from the digital program using the chair-side computer to determine the location of final restoration. The most appropriate 3-dimensional surgical location of implant in jaw bone is determined based on the anticipated final restoration, followed by STL file extraction and data input to the milling machine (VARO-mill; Neobiotech, Seoul, Korea) to produce a VARO Guide within 15 minutes. This surgical guide allows the implant to be accurately operated and planted in the planned area, all of which could be done within patient’s single visit.

Immediate loading of dental implants is defined as being earlier than 1 week subsequent to implant placement.\textsuperscript{3} In general, most patients that receive implant therapy may experience discomfort associated with not only the rough preparation process and the following pain on the day of surgery, but also the inability to chew food on the affected area for about three months after surgery. Immediate restorations are installed to provide immediate chewing function. The indications for immediate loading of single-implant crowns are limited to situations where primary implant stability of insertion torque is in the range of 30 to 55 Ncm, and when systematic or local contraindications like parafunctional activities or large bone defects are absent.\textsuperscript{3}

Fig. 1. Preoperative panoramic view showing missing both mandibular molars.
porcelain fracture on #45 (Fig. 1). The alveolar ridge of mandibular posterior region had knife edge shape and showed inadequate amount of keratinized mucosa. The patient had been previously treated with removable partial denture on mandibular dentition 9 years ago at a local clinic. She refused to use the old denture because of mucosal pain due to the ill-fitting denture base.

Upon thorough clinical and radiographic examinations, problem lists were made including loss of mandibular molars, masticatory inconvenience, and ill-fitting denture. In order to improving masticatory function, four main key points were considered in order to solve these problems; (1) restoration of missing site, (2) immediate fixed provisional restorations, (3) top-down and restoration-driven guide surgery, (4) quick, accurate and simple treatment. Crown restorations on #25, #26 were planned to restore the occlusal surface of fractured and worn dentition. Fixed restorations with 4 new implants were also planned for missing sites of mandibular molars.

On the day of surgery, the impression of mandibular left molars, #36, #37, was taken using Pre-Guide (NeoBiotech, Seoul, Korea) (Fig. 2A) and light-cured inside the mouth. Pre-Guide containing radiographic markers on the site of surgery was installed and CT was taken. Surgical guide was remodeled in 3D designing program called VARO Plan (NeoBiotech, Seoul, Korea) (Fig. 2B). Firstly, CT images were reorganized in the program and the sites for crowns and fixtures were determined. The size of Pre-Guide template was selected and 3 points of radiographic markers in the software were superimposed with the corresponding points of scanned Pre-Guide in CT images. The locations for crowns were decided based on Top-down implant dentistry. Next, panoramic image was reorganized with CT images and the canal for inferior alveolar nerve was marked. Appropriate dimensions, including diameter and length, of implant fixtures (CMI IS-III, NeoBiotech, Seoul, Korea) were selected and implants were positioned on the site of mandibular left molars while insuring that enough distance from the fixture to the inferior alveolar nerve was available. The implant

Fig. 2. 1-visit VARO guide (NeoBiotech, Seoul, Korea) implant surgery on #36, #37. (A) Pre-Guide (NeoBiotech, Seoul, Korea) positioning on #36, #37, (B) CAD for implant positioning on #36, #37, (C) CAM of Pre-guide with VARO Mill (NeoBiotech, Seoul, Korea), (D) performing the VARO guide (NeoBiotech, Seoul, Korea) implant surgery, (E) measuring the insertion torque of implants, (F) completion of 1-stage implant surgery.
dimensions of 4.5 mm diameter with 8.5 mm length was selected on the site of mandibular left 1st molar, and 5.0 mm diameter with 7.3 mm length on the site of mandibular left 2nd molar. After deciding the location of implant fixtures, offset of surgical guide was set and file was extracted in STL format. STL file was put into the milling machine, so called VARO Mill (NeoBiotech, Seoul, Korea), and a 2-hole-guide was fabricated (Fig. 2C).

Incision and flap repositioning was planned in order to preserve keratinized attached gingiva. Two internal type hex implants (CMI IS-III; NeoBiotech, Seoul, Korea) were installed on mandibular left molars with putting the guide on the proximal dentition. 4.5 mm diameter with 10.0 mm length implant(CMI IS-III; NeoBiotech, Seoul Korea) was also installed on the site of maxillary left 2nd molar using free-hand-technique (Fig. 2D). Insertion torque was measured to be 25 Ncm on the maxillary site and 20 Ncm on both of the mandibular sites (Fig. 2E). According to loading protocol (IT consensus document, JOMI, 2014), conventional loading was recommended. 1-stage-surgery was performed with flap repositioning to gain keratinized mucosa and healing abutments were tightened (Fig. 2F).

During the first 3 months following surgery, healing of soft tissue and preservation of keratinized mucosa was observed, and implant stability test using AnyCheck (NeoBiotech, Seoul, Korea) consistently showed values over 80. After the 3 month healing period, final impression for zirconia implant crowns was performed on mandibular left molars using transfer copings (NeoBiotech, Seoul, Korea). Impression was taken with PVS (I-SiL Jumbo; Spident, Incheon, Korea) and bite registration was also performed with PVS material (Imprint bite; 3M, St. Paul, MN, USA).

Treatment of the mandibular right molar region begun with taking an impression and a CT scan of mandibular right molars using a new Pre-Guide. Just as it was in the treatment of mandibular left molars, surgical guide was made through the same process from designing to milling with the total processing time of 2 hours (Fig. 3A, B). 4.0 mm diameter with 8.5 mm length implant (CMI IS-III; NeoBiotech, Seoul, Korea) was installed on the site of #46, #47. (A) CAD for implant positioning on #46, #47, (B) CAM of Pre-guide (NeoBiotech, Seoul, Korea), (C) performing the VARO guide (NeoBiotech, Seoul, Korea) implant surgery, (D) measuring the insertion torque of implants, (E) fabrication of immediate provisional restorations.

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right 1st molar, and 4.5 mm diameter with 7.3 mm length implant (CMI IS-III; NeoBiotech, Seoul, Korea) was installed on the site of right 2nd molar with the same flap design as the left side to preserve keratinized mucosa (Fig. 3C). Insertion torque was 40 Ncm and 50 Ncm, respectively, and based on loading protocol, immediate loading was planned (Fig. 3D). After flap repositioning and suture, temporary titanium abutments (NeoBiotech, Seoul, Korea) were connected to the fixtures. After sealing each of the abutment hole with a thin wood stick, resin (Unifast Trad; GC, Tokyo, Japan) was poured and temporary crowns were fabricated (Fig. 3E, Fig. 4). On left side, zirconia crowns that had been fabricated through final impression (Exocad, Germany / Zirkonzahn, USA) were inserted. Through this series of loading, the patient was able to chew food bilaterally.

After 3 months, final impression was performed for right molars by transfer technique with impression copings (NeoBiotech; Seoul, Korea) and PVS material (I-Sil Jumbo, Spident, Incheon, Korea). On the next visit, zirconia crowns were inserted and adequate amount of keratinized mucosa was observed around crown and abutment (Fig. 4, Fig. 5).

**Discussion**

Guided implant surgery has been reported to be more accurate and precise than conventional surgical guides or free-hand implant placement\(^4\,5\). Surgeons can achieve a predictable result by using surgical guide. Especially in multiple-implant cases in partially edentulous sites, guided surgery should be considered over free-hand.
A technique to improve the accuracy of implant placement. Also, surgical guide reduces discrepancies caused by differing levels of operator experience. According to previous study, there were significant deviations for the coronal and depth positions in implant surgery by free hand technique of inexperienced surgeon compared to experienced surgeon. Guided surgery facilitates better results for dentists who have insufficient experience in performing implant surgery.

Guided implant surgery often allows minimally invasive surgeries without the necessity to elevate a surgical flap. Patients can also benefit from reduced post-operative pain, as well as the time it takes for surgery. Also, guided surgery can predict the location of maxillary crown portion and enable fabricating provisional restorations by CAD-CAM for immediate loading protocols. With the combination of guided surgery and immediate loading, patient-friendly surgery can be ultimately achieved.

Guided implant surgery can be generally being classified as either dynamic or static. Computer-aided navigation system allows for a real-time implant surgery. Nevertheless, due to its simple accessibility and accuracy comparable to navigation system, static guides are more commonly used. A static guided implant surgery is based on 3D images of CBCT and intraoral scanned images or model gained from impression. Computer-aided-design -computer-aided-manufacturing (CAD-CAM) programs enable virtual implant planning and guide fabrication. Fabricated guide is seated on the planned surgical site and sometimes additional fixation through mini-screws or pins is used. The number and the location of teeth used to support the surgical guide can significantly influence the accuracy of the surgical guide, with 4 teeth providing equal degree of accuracy compared to a full-arch guide.

Currently, the combination of implant planning software for exporting STL files and chair-side 3D printer for fabrication of guide can be utilized as an alternative way of guided surgery process. A previous study has re-
ported that 3D printed surgical guides from in-office 3D printers are 10 times less expensive than laboratory CAD-CAM surgical guides. Therefore, chair-side fabricated guide can be chosen as the first option of guided surgery in the near future.

Guide manufacturing system can be also classified according to its fabrication method: printing or milling. 3D printer fabricates a surgical guide by adding resin, whereas milling machine fabricates by cutting a resin block. For milled guides, the radiographic templates can be converted into a surgical guide. Park et al. reported that the mean horizontal and vertical errors of digital guides made by the 5-axis milling method were 0.14 mm and 0.20 mm and that the maximum errors were 0.68 mm and 0.41 mm. Another study showed that the mean deviation of the surgical guide is 0.16 ± 0.06 mm. Meanwhile, printed guide made by stereolithography (SLA) showed maximum errors of 0.22 to 0.24 mm. Thus, two different methods have no difference in accuracy and have acceptable precision.

In this case, there are several clinical implications: (1) VARO Guide (NeoBiotech, Seoul, Korea) is very effective in performing and learning restoration driven implant dentistry. (2) For the elderly, treatment can be performed to restore the masticatory function through the combination of chair-side fabrication of surgical guide and immediate loading after surgery. (3) The 3-dimensional placement of implant is pre-determined before surgery and guided to coincide with the direction of the occlusal force, therefore minimizing long-term complications (mechanical & technical & periodical). (4) Through the incision and flap controlling, enough keratinized mucosa over 4 mm width could be preserved.

Even with the achievement of successful restorations, there were some limitations. First of all, large mass of resin block tray can cause polymerization shrinkage during curing stage which could result in errors. To minimize this shrinkage, clinicians should perform curing while the guide is seated in patient’s dentition and repeat cutting and adding resin in order to maintain a passive fit of resin tray. Secondly, clinicians should recognize that the implant placement may be more difficult because the lack of vertical space for adapting surgical guide and drill simultaneously. Lastly, irrigation to surgical site can be limited as it must pass through the guide and could cause the site to become overheated. During surgery, additional irrigation is needed to prevent BIC (bone to implant contact) failure. Further studies will be needed to complement these limitations and improve the effectiveness of patient-friendly, chair-side process of surgery and restorations.

**Conclusion**

In the case of bilateral loss of molars, disadvantages of long surgical procedure and subsequent healing period is inevitable. However, by utilizing the combination of restoration-driven treatment planning and the chair-side design and fabrication of surgical guide, clinicians can pursue immediate restorations to restore chewing functions with minimum complications.

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진료실 CAD-CAM에 의한 컴퓨터 가이드 임플란트 수술과 즉시
임시보철치료: 증례보고

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치과와 기공실을 오가며 복잡하게 진행되는 기존 CAD-CAM 컴퓨터 가이드 제작 방식을 단순화하기 위하여, 진료실에 설치한 바로가이드 시스템(VARIO Guide, CAD, Pre-Guide, VARO-mill, NeoBiotech, Seoul, South Korea)을 통하여 Top-Down 개념과 수복 주도 개념을 적용하여 1-day 수술과 임시보철을 완료하는 증례를 보고하고자 한다. Pre-Guide 를 통해 환자의 중심위에서 교합을 채득하고 CT를 촬영하며, 진료실 내 컴퓨터에서 CAD를 통해 바로가이드를 1시간 내에 제작하였다. 미리 제작된 광중합 레진이 담긴 Pre-Guide 트레이를 술부에 위치시킨 후 중심위에서 CT를 촬영하였다. CT 데이터가 진료실 내 컴퓨터로 전송되면 수복 위치를 정한 후 이어서 3차원적으로 턱뼈에서 임플란트를 식립할 위치를 자동하여 STL 파일로 추출하였다. 그리고 진료실에 설비된 밀링 기계(VARIO-mill)에 Pre-Guide를 고정하여 수술용 가이드를 15분 내에 제작한다. 이 가이드로 환자는 한번 내원하여 임플란트를 계획한 위치에 안전하고 정확하게 수술해 주며, 초기고정력이 양호한 임플란트에 대해서는 즉시임시치아까지 장착해 주어 환자에게 즉시 기능이 가능하도록 할 수 있었다. (대한치과보철학회지 2021;59:478-86)

주요단어
CAD-CAM, 즉시수복, 환자친화적, Pre-Guide, Top-Down, 수복주도, 바로가이드

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