Case Series

Computer-assisted Navigational Surgery Enhances Safety in Dental Implantology

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Abstract

Introduction: Dental implants are increasingly used to restore missing dentition. These titanium implants are surgically installed in the edentulous alveolar ridge and allowed to osteointegrate with the bone during the healing phase. After osseo-integration, the implant is loaded with a prosthesis to replace the missing tooth. Conventional implant treatment planning uses study models, wax-ups and panoramic x-rays to prefabricate surgical stent to guide the preparation of the implant site. The drilling into the alveolar ridge is invariably a "blind" procedure as the part of the drill in bone is not visible. Stereotactic systems were first introduced into neurosurgery in 1986. Since then, computer-assisted navigational technology has brought major advances to neuro-, midface and orthopaedic surgeries, and more recently, to implant placement. Clinical Feature: This paper illustrates the use of real-time computer-guided navigational technology in enhancing safety in implant surgical procedures. Outcome and Conclusion: Real-time computer-guided navigational technology enhances accuracy and precision of the surgical procedure, minimises complications and facilitates surgery in challenging anatomical locations.

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Key words: Avoiding iatrogenic injuries, Computed aided surgery, Computerised navigation, Direct virtual vision, Implant surgery, Navigation dentistry

Introduction

While the surgical procedure of placing dental implants may seem technically simple, it is not straightforward and requires careful preoperative planning.

Surgical preparation of the implant site in conventional implant treatment is guided by a surgical stent (Fig. 1) prefabricated from study models with wax-up and input from two-dimensional panoramic X-rays.[1,2] Anatomical defects and vital structures in the vicinity of the drill are not seen during conventional implant surgery.[3] Iatrogenic injuries can occur and are unpleasant events for both clinicians and patients.

The ability to visualise an imaging of the drill in the bone and the adjacent anatomical structures in real time would greatly reduce any iatrogenic injuries. Hence, this would minimise surgical risks and optimise clinical results.

Since the introduction of navigational surgery in neurosurgery in 1986,[4] navigational technology has advanced numerous surgical procedures in the head and neck region.[5] Similarly, computer-assisted navigational surgery in implant dentistry has shown to outperform conventional implant planning, which is based on two-dimensional dental images.[6]

This paper illustrates the use of real-time computer-assisted technology, the Image Guided Implantology (IGI™) system, to improve safety, especially in patients with challenging surgical anatomy.

Real-time Navigation Technology in Dental Implantology - IGI™

This real-time navigational technology is based on the global positioning system (GPS) concept, transferred to the human anatomy.[7]

The anatomy of the patient's jaw, with a dental splint

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incorporating special fiducial markers, is first captured on CT. This CT anatomy forms the virtual patient. The fiducial markers superimpose the virtual patient on the real patient during surgery.

During surgery, the IGI™ System tracks the position of the patient's jaw and the drill through signals from the infrared light emitters fitted to the patient and surgical instruments. The spatial position of the drill in relation to the patient is calculated by the system's processing unit and is visually displayed in real-time on the navigation screen.

The system guides the surgeon to prepare the receptacle site in accordance with the planned position of the implant. The virtual position, angulation and depth of the drill tip are displayed in real time in relation to the pre-acquired CT image of the anatomical structures.

Any deviation from the planned path of drilling will trigger an audio and visual alert. This guides the surgeon to maintain the planned course and avoid encroaching on critical structures during surgery.

Patient 1

Conscious Compromise to Avoid the Inferior Dental Nerve in a Resorbed Mandibular Ridge

This patient requested for implant replacement of her missing #45 and #46. The patient did not want any bone-grafting procedure.

The residual alveolar ridge in the region was markedly resorbed and knife-edged. The #47 had a slight mesio-angular tilt and the #43 a slight distal tilt. The saddle at inter-contact level was 16 mm and at alveolar crest, 23 mm. The tilting of the adjacent teeth made the saddle less than ideal for implant prosthodontic rehabilitation.

The anatomical challenges of this case were:

- the mesio-distal length of the ridge at crestal level was sufficient to place 3 regular-sized implants whilst that at the inter-contact level could accommodate 2 large molar pontics (Fig. 2).
- the ridge was knife-edged and resorbed. This restricted the diameter and length of the implant fixtures that could be used in this region (Fig.3).
- the inferior dental nerve was in close proximity to the crest (Fig. 4).

To obtain optimal prosthodontic rehabilitation and to avoid nerve injury and cortical plate perforation, various implant sizes, positions and angulations were simulated on the virtual patient before finalising the treatment plan.

The conscious compromised treatment was 2 fixtures to accommodate an implant-supported 3-unit bridge with a reduced pontic at the centre (Fig. 5).

The conscious compromised treatment plan was carried out with real-time navigational guidance that overcome the anatomical limitations for optimal implant length and size without nerve injury (Fig. 6).

Patient 2

Avoiding the Adjacent Roots in a Narrow Span in the Maxilla

This patient had lost her #12 and buccal alveolar plate in

Fig. 1. Surgery guided by prefabricated stent.

Fig. 2. Patient 1: Missing #45, #46.

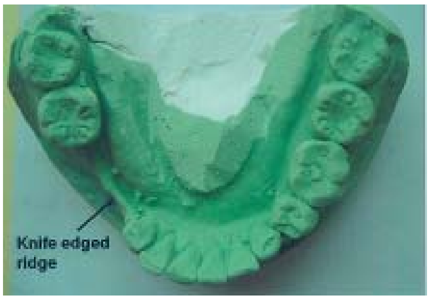

Fig. 3. Patient 1: Knife-edged ridge.

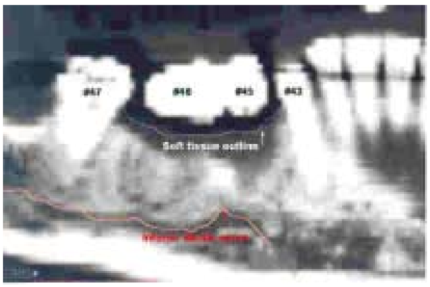

Fig. 4. Patient 1: Inferior dental nerve close to the ridge.

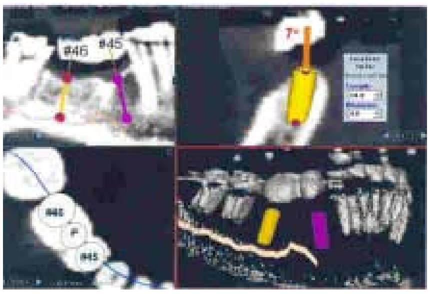

Fig. 5. Patient 1: Implant-supported 3-unit bridge.

an accident (Fig. 7). She requested for an implant to replace the missing tooth. The defect was thus grafted to receive implant replacement.

As the tooth lost was a small upper lateral incisor, the mesio-distal ridge saddle was only 6 mm.

The narrowest Branemark implant available at that time was of 3.3 mm diameter. This gave a safety margin of 1.35 mm from the adjacent roots (Fig. 8).

As this was an upper anterior tooth, the challenge was not only the narrow span and buccal plate defect, but aesthetics.

For optimal aesthetics, the implant was placed midway between the 2 adjacent teeth and at zero-degree angulation through the cingulum.

The optimal position and angulation of the implant planned was as in Figure 9.

The implant was placed under navigational guidance in a position and angulation that avoided compromising the adjacent teeth (Fig. 10), and facilitated an aesthetic prosthodontic rehabilitation (Fig. 11).

Patient 3

Avoiding Converging Roots in the Mandible

This patient had a wide diastema between #43 and #42 (Fig. 12). The adjacent dentition was virgin teeth. The patient requested for the closure of this diastema with an implant-supported tooth. He was adverse to denture and bridge.

The 2 adjacent roots were converging apically and lingually. In addition, there was a buccal concavity of the ridge (Fig. 13).

The edentulous space was 3.88 mm at the lingual side and 7.51 mm at the buccal side. The prosthodontist requested for a regular platform implant of diameter 3.75 mm for a good emergence profile and aesthetics.

The buccal concavity was grafted prior to the implant surgery.

In order to avoid the converging roots, the implant had to be positioned slightly off mid-arch towards the buccal cortex, but angulated slightly lingually to facilitate rehabilitation with an implant crown (Fig. 14).

The implant was placed safely between the converging roots, guided by real time navigation. As the implant was in a unique position, 2 postoperative periapical radiographs were taken at different angles to verify the postoperative integrity of the converging roots (Fig. 15).

Patient 4

Navigational Surgery in Sinus Lift Implant Placement

This patient requested an implant in the left maxillary free end saddle to replace the #26.

The sinus floor was 8 mm above the alveolar crest at the proposed implant site. As the proposed crown would be the only molar to withstand the occlusal load on the left side, the attending prosthodontist requested for a wide platform implant with a minimum length of 10 mm.

The plan was to lift the sinus floor by 2 mm through a simultaneous intra-alveolar sinus lift during implant placement (Fig. 16).

In conventional intra-alveolar sinus lift, the preparation of the receptacle site is a closed drilling process guided by a prefabricated stent. The drilling stops when the surgeon perceives that the drill tip has reached the sinus floor. This is followed by tapping the sinus floor upwards with an osteotome.

This blind surgical procedure depends very much on the clinical perception of bone density. Touch perception of bone density is technique-sensitive and carries a 24% risk of perforation of the sinus floor.[8]

During navigation surgery, the virtual sinus floor is locked exactly onto the real sinus floor. This allows a virtual direct vision of the drill tip and the sinus floor in real time. Under virtual direct vision, the preparation of the receptacle site stops just short of the sinus floor. The weakened sinus floor is in-fractured and raised.

The sinus lift surgery was uneventful. The postoperative radiograph showed the outline of a raised in-fractured sinus floor (Fig. 17).

Patient 5

Avoiding Perforating the Maxillary Sinus

The patient requested implant rehabilitation to replace a failed cantilever bridge in his left maxilla, from #24 to #27. The pontics were at #24 and #26.

The maxillary sinus at #26 dipped disto-buccally with only 8.33 mm of ridge height at this site. An implant of 8 mm or less placed at mid crestal of #26 and perpendicular to the occlusal plane would not encroach on the sinus (Fig. 18).

However, on analysis of the CT anatomy and evaluation of various treatment options on the virtual patient, an implant of 13 mm length placed in a conscious compromised position and angulation would not encroach on the sinus and also avoided the need of a sinus lift for the longer implant.

The implant was positioned at 1 mm mesial and 0.8 mm palatal from mid crestal of #26 saddle and angulated 2° mesial and 4° palatal to the occlusal plane to avoid the sinus (Figs. 19 and 20).

Discussion

Conventional dental surgery is a closed procedure. Within

Fig. 6. Patient 1: OPG showing implants seated.

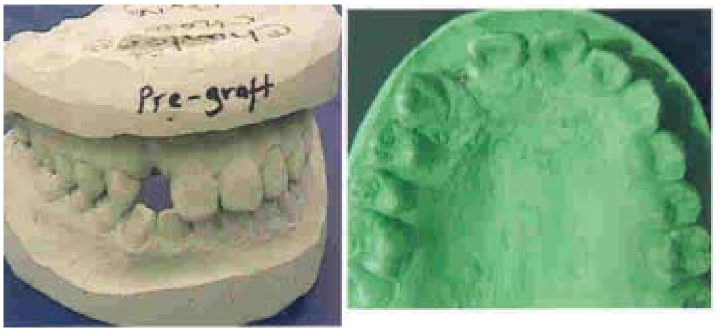

Fig. 7. Patient 2: Missing #12.

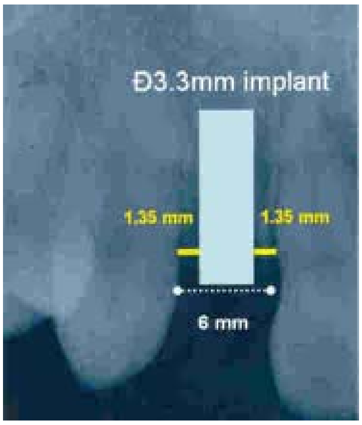

Fig. 8. Patient 2: 6-mm saddle with 3.3-mm (diameter) implant.

Fig. 9. Patient 2: Postoperative X-ray of implant #12.

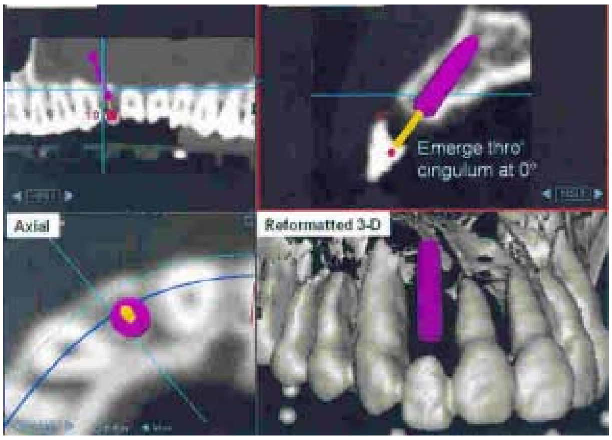

Fig. 10. Patient 2: Surgical plan.

Fig. 11. Patient 2: Final prosthesis (Photo courtesy of Dr Dennis Leong).

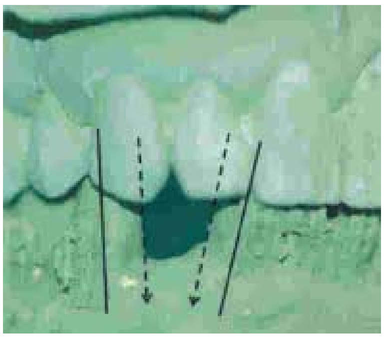

Fig. 12. Patient 3: Diastema between #42 and #43.

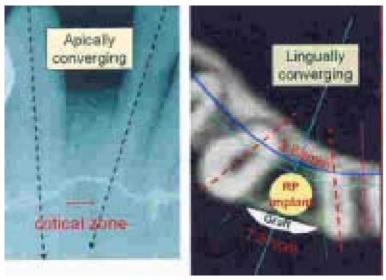

Fig. 13. Patient 3: Coverging roots, #42 and #43.

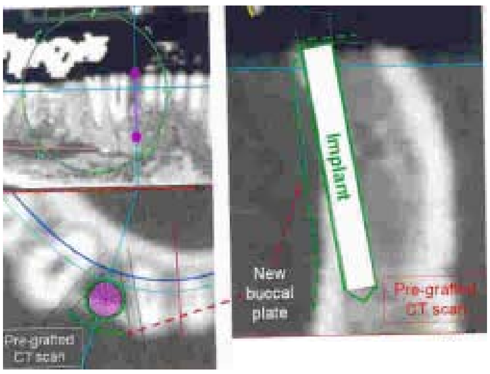

Fig. 14. Patient 3: The implant position.

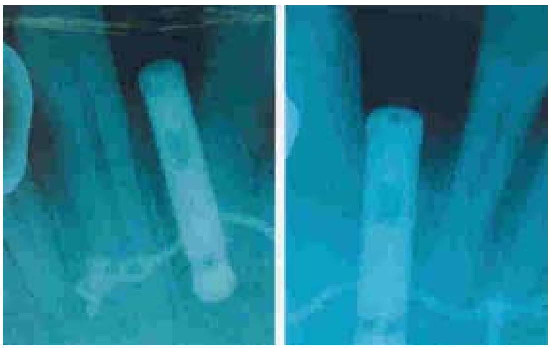

Fig. 15. Patient 3: Postoperative radiographs.

Fig. 16. Patient 4: Sinus lift implant placement.

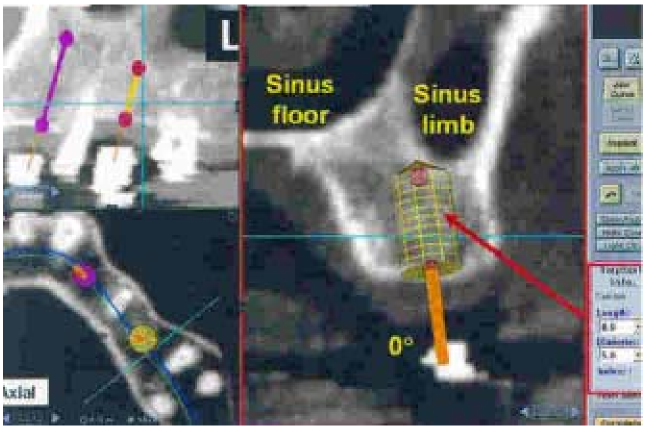

Fig. 18. Patient 5: Implant per conventional plan, 5.00 mm (d) x 8 mm (l).

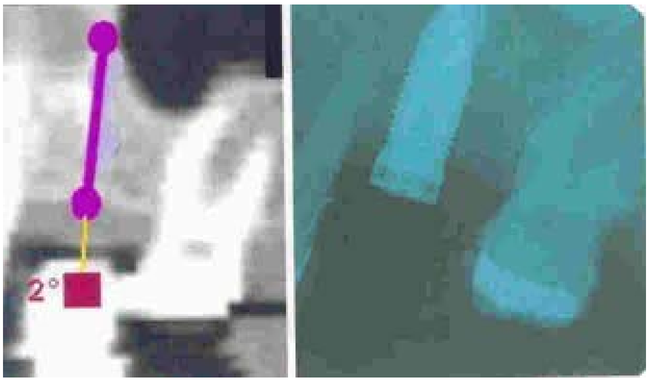

Fig. 20. Patient 5: The digital plan vis-a-vis postoperative radiograph.

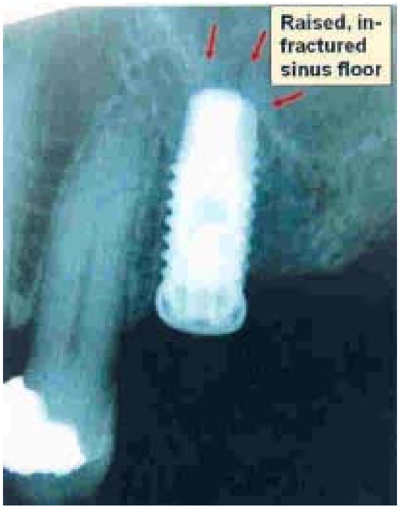

Fig. 17. Patient 4: Raised sinus floor.

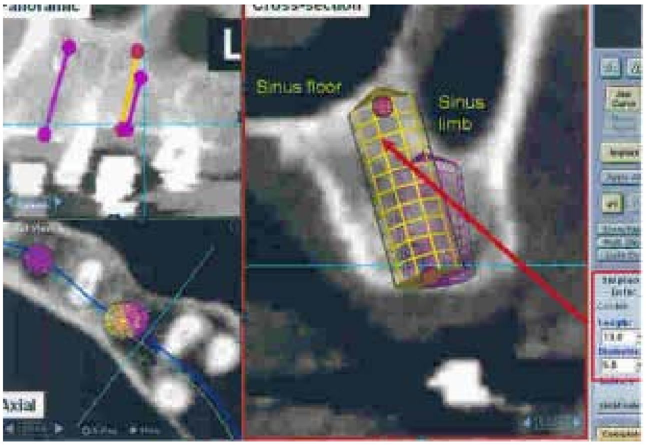

Fig. 19. Patient 5: The slightly angulated implant of 5.0 mm (d) x 13 mm (l).

our jaw bones are many critical structures. The main goal of navigational implantology is to minimise the risk of iatrogenic injury to vital anatomical structures in the maxilla and mandible.[7] Navigational surgery definitely reduces the risk of iatrogenic injuries as unseen structures are visualised by direct virtual vision through the system.

The accuracy of implant placement under navigational guidance depends on 2 important factors, the reliability of the navigation system and the learning curve of the surgeon.[9] Clinicians intending to benefit from navigation surgery need to evaluate the various systems available. Factors to consider include the accuracy of the system, the user-friendliness of the hardware and software, the learning curve needed to master the system, the additional cost and safety to the patients.

In the infra-red light tracking navigational system, a straight path between the navigation camera and the operative site is essential during surgery. Hence, the surgeon and his assistant have to position themselves to avoid intercepting this straight path. The seating arrangement of the surgeon and the assistant during surgery may need to be re-orientated.

As CT imaging exposes patient to higher radiation than conventional panaromic radiographs, the clinicians may need to weigh this factor vis-à-vis the advantages of navigational technology when planning implant treatment.

Conclusions

In areas of complex anatomy, computer-aided navigational surgery is definitely superior to conventional implant surgery in treatment planning and avoiding iatrogenic injuries.

With navigational technology, implant surgery need not be "blind". With real-time direct virtual vision, both surgeons and patients are reassured of surgical safety. This increases the confidence and reduces surgical stress in both the patient and the clinician.

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