Journal of Taibah University Medical Sciences (2020) 15(2), 153–159

Taibah University

Journal of Taibah University Medical Sciences

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Case Report

CAD-CAM surgically-guided oral implant site expansion and implant placement in severely atrophic maxilla

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Received 3 December 2019; revised 25 February 2020; accepted 29 February 2020; Available online 23 March 2020

الملخص

يواجه أخصائي زراعة الأسنان تحدي كبير عند إعادة التأهيل الفموي لحالات الامتصاص العظمي للفك العلوي. هذا التقرير يسرد علاج مريض يبلغ من العمر ٥٤ عاما ويشتكي من عدم ثبات طقم الأسنان العلوي. الفحوصات السريرية والأشعة التشخيصية أظهرت امتصاص عظمي أفقي وعمودي للفك العلوي للمريض

تم عمل أشعة مقطعية للفك العلوي ومن ثم عمل تخطيط لوضع الزرعات باستخدام برنامج مختص في مجال زراعة الأسنان، من ثم تم تصميم دعامة جراحية موجهة بالحاسوب كدليل جراحي للمساعدة في وضع زرعات للفك العلوي للمريض. يصف هذا التقرير طريقة الإرشاد الكامل لوضع زراعة الأسنان ابتداء من استخدام المثقاب الأول إلي إدخال الزرعة عن طريق الدليل الإرشادي، وليس هذا وحسب بل تم عمل توسعه للعظم في أماكن محددة عن طريق إدخال أداة التوسيع من خلال الدليل الإرشادي لضمان وضع الزرعات في المكان المخطط له. بعد وضع الزرعات تم عمل أشعة مقطعية أخرى ومن ثم تمت عملية مطابقة الأشعة الأولى التي تحتوي على الخطة العلاجية لأماكن الزرعات قبل العملية بتلك الأشعة التي تحتوي على الزرعات بعد العملية. تبين وجود انحراف بسيط جدا عن الخطة العلاجية مقارنة بما نشر مؤخرا مما يبين إمكانية استخدام الدعامات الموجهة بالحاسوب لتسهيل تثبيت الزرع وتوسيع العظم. بالطبع، لا يمكن استخلاص استنتاج محدد من تقرير الحالة، وسيلزم إجراء مزيد من تجارب المراقبة العشوائية باستخدام عينات كبيرة للوصول إلى استنتاجات سليمة.

الكلمات المفتاحية: توسعة العظم؛ الدعامة الجراحية بنظام الكاد كام؛ زراعة الاسنان؛ انحراف زرعة الاسنان؛ موسعة العظم

Abstract

During the rehabilitation of patients with atrophic maxilla, an oral implantologist may face a challenge in achieving accurate implant placement. We present a 54-year-old man who is completely edentulous with a history of unretentive conventional complete dentures. The patient sought help for a fixed implant prosthesis and disagreed with the proposed plan to restore his missing teeth using a removable prosthesis. Clinical and radiographic examinations showed a severely resorbed maxilla with horizontal and vertical bone deficiency. A computer-guided surgical stent was used to place implants in the atrophic maxillary ridge. A double cone beam CT (CBCT) scan procedure was performed. The first scan of the patient's jaw was done using a radiographic scan appliance, and the second scan was done only with the scan appliance. This was followed by virtual implant planning, after which we designed and printed the CAD-CAM surgical stent. From the pilot drill to the final one, implant site preparation was done using a guide. Furthermore, ridge expansion and implant fixture placement were performed using a planned surgical guide to ensure accurate and precise implant placement. Next, a postoperative CBCT was done to determine the accuracy of the computer-guided stent using In2guide Pro Software. By superimposing the preoperative plane onto the postoperative scan, the postoperative CBCT was aligned on the same axis as the preoperative image. This case report shows that computer-guided stents for severely atrophic maxilla can potentially be used to facilitate both implant installation and bone expansion. However, in order to reach sound conclusions, further randomised control trials with large sample sizes should be carried out.

Keywords: Bone expansion; CAD-CAM surgical stent; Dental implant; Implant deviation; Osteotome

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Peer review under responsibility of Taibah University.

ELSEVIER Production and hosting by Elsevier

 https://doi.org/10.1016/j.jtumed.2020.02.006

Introduction

Sufficient high-quality bone volume has been regarded as the major predictor in rehabilitation with osseointegrated implants. In patients with thin edentulous ridge atrophy, augmentation is required. Several techniques are available to augment the atrophic bone prior to implant placement. These include bone grafting,[1,2] guided bone regeneration,[3] and distraction osteogenesis.[4,5] These methods have several drawbacks such as invasiveness as surgical procedures, resorption of grafting materials, exposure to infection, and delayed implant installation to accommodate grafting maturation.[3,6]

Referred to as bone spreading or the osteotome technique,[7] ridge expansion is a less invasive method for preparing the atrophied ridge for implant placement. However, osteotome misdirection during the expansion process is not uncommon and can result in a change in the prepared site direction, leading to a malposed implant.

Various methods are available for determining exact implant positioning. Such methods range from free-hand positioning, simply guiding the pilot drill, and guided preparation of the implant cavity to fully-guided implant insertion.[8] It has been demonstrated that implant cavity preparation that involves three-dimensional planning and guiding has yielded higher accuracy than free-hand implant insertion. As such, even experienced surgeons would benefit from three-dimensional guidance.[9,10]

Recently, accurate implant placement has been a major concern due to the numerous biomechanical issues that can arise from incorrect positioning. Prosthetic-driven implant placement that includes a diagnostic wax-up of the prosthesis, radiographic evaluation, virtual implant planning, and CAD-CAM surgical guide construction prior to the implant placement visit, is recommended not only to consider available residual bone, but also to aid with the proper positioning of planned implants.[11]

Therefore, in order to guide implant installation, "dual purpose" templates have emerged for use in both radiographic examinations and during surgery. Unfortunately, these templates have only proven helpful for correct implant positioning during the first round of drilling, and they are not as effective during the latter stages of surgery.[12] Computer-aided implant placement has been introduced to solve all of these problems. Through CT scans, it has significantly improved diagnosis and treatment planning in the field of implantology. In addition, it has also enabled high-accuracy implant placement through 3D visuals.[13]

In this case report, a computer-guided surgical stent was used to place implants in an atrophic maxillary ridge. Furthermore, ridge expansion and implant placement were performed using a planned surgical guide to ensure accurate, precise implant placement.

Clinical report

A completely edentulous 54-year-old patient was presented to the prosthodontics department in the faculty of dentistry at Cairo University. He had a history of unretentive conventional complete dentures. The patient asked for a fixed implant prosthesis, rejecting the idea of restoring his missing teeth with a removable prosthesis. The patient claimed to be medically free and did not complain of any systemic diseases. Clinical and radiographic examinations revealed a severely resorbed maxilla with horizontal and vertical bone deficiency. An extra-oral examination showed a loss of lip support and normal temporomandibular joint (TMJ) movement with normal mouth opening.

Two years ago, the patient received upper fixed implant-supported prostheses with two implants installed at the first premolar areas. After six months, the prostheses failed (one implant showed severe bone loss while the other implant fractured at its coronal part). After the removal of the failed prostheses, the patient was given only one implant in the upper right second premolar area (Figure 1).

Pre-operative planning

Diagnostic maxillary and mandibular casts were mounted on an articulator. A diagnostic wax-up and setup were made to visualise both the anatomy and the ideal position of the planned implants. A duplicate of the wax-up was then converted to a radiographic guide. This had small balls of a radio-opaque material that were placed in prepared holes and randomly distributed on different surfaces using the guide.

This was followed by a double scan protocol, the patient's first CBCT scan with the template, and a second scan of the radiographic guide only. The CBCT data were then imported into the In2Guide software (Cybermed Inc., Seoul, Korea).

To ensure an aesthetically-pleasing result, the dental implants were then virtually planned according to the patient's anatomy. The plan entailed the placement of five implants in the edentulous maxilla to support full-arch fixed prosthesis. The implant sites were as follows: 17, upper right second molar area; 12, upper right second premolar area; 12, upper right lateral incisor area; 22, upper left lateral incisor area; and 17, upper left second molar area. All implants were 3.7 mm in diameter and 8 mm long, with the exception of the implant at 12 (upper right lateral incisor), which was 10 mm long. Based on the CBCT, it was evident that the implant site widths at 12 and 15 were 2.7 mm and 2.8 mm, respectively; hence, these areas required bone expansion to facilitate the installation of an implant with a diameter of 3.7 mm (Figure 2).

The finished plane was emailed to the manufacturer for fabrication of the surgical template. The stent was fabricated

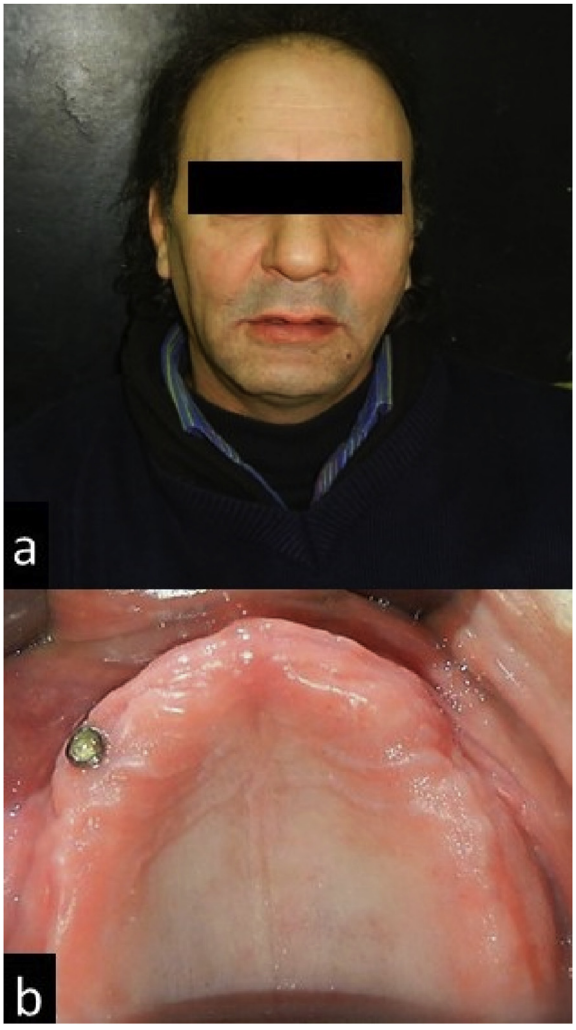

Figure 1: a; Preoperative extra-oral frontal view, b; Preoperative intraoral occlusal view.

with modifications, with the anterior part having an open window to allow for adequate irrigation. The surgical stent was 3D printed (on a DDD printer from Envision Tech Gmbh) using a clear, biocompatible, FDA-approved material (Figure 3).

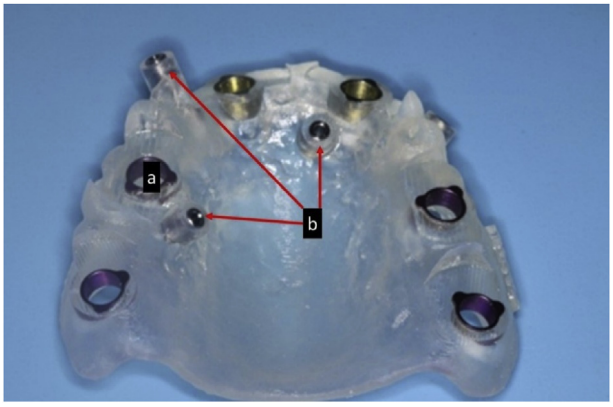

Figure 3: 3D printed surgical stent, a; Metal sleeve, b; Fixation screw access.

Surgical procedure

As a prophylactic measure, the patient was instructed to take 2 gm of amoxicillin 2 h before the surgery. Surgical site preparation was carried out according to the standard method. The maxillary arch was locally anesthetised (using Optocaine, 20 mg/ml with adrenaline 1:80,000, Molteni Dental), The computer-guided stent was placed intra-orally, then stabilised using fixation anchor screws, as planned preoperatively (Figure 4).

Using In2Guide's surgical kit, the anchor screws were drilled in place at the proposed site. Irrigation was strictly ensured during all drilling.

Drilling was carried out according the In2Guide Kit sequence's directions. The soft tissue removal drill was utilised to remove soft tissue, then the computer-guided keys were used to begin drilling. At all sites, they were inserted into the sleeves according to the planned width and length, starting with the pilot drill.

Implant site expansion was executed at areas 12 and 15 as follows: pilot drilling was done to a depth of 8 mm, and bone condensation was attained through radial reinforcement using a series of tapered-tip bone condensation devices (Bone Condenser Xive, Dentsply Friadent) that had diameters of 2.2 mm−3.5 mm, which were appropriate for widening the implant bed. The osteotomes were placed using the guided stent sleeves to control expansion in the target areas (Figure 5). The implant bed's final diameter was established

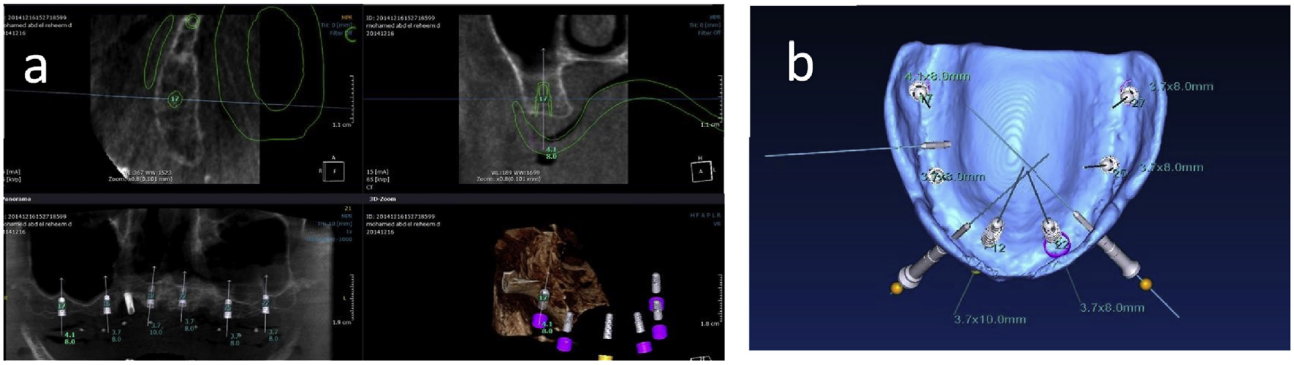

Figure 2: Virtual planning of dental implants, b; Surgical stent planning.

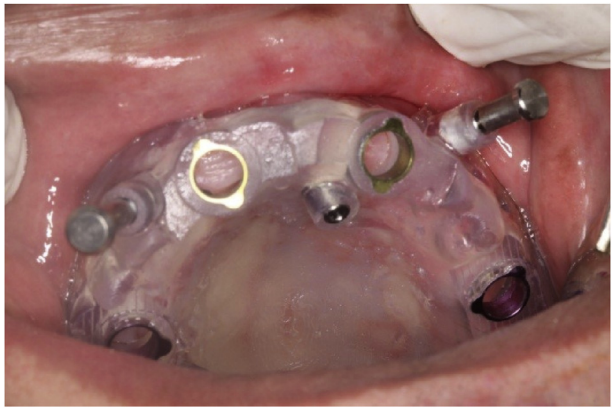

Figure 4: The computer-guided stent stabilised using fixation anchor screws.

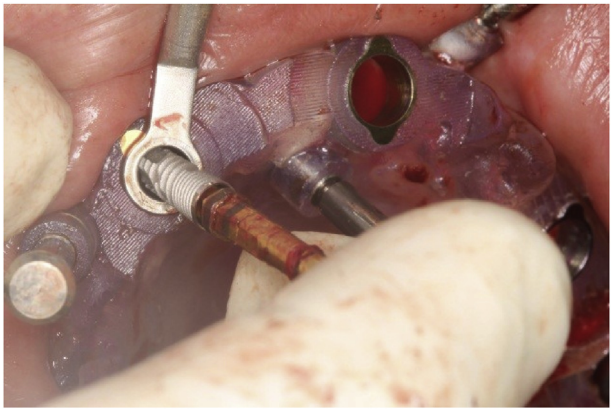

Figure 6: Implant fixture installed through guided stent sleeves.

with crestal bone thickness reaching 6 mm buccolingually. The final drill was then carried out at the two sites to prepare for implant installation (Figure 6).

At all of the other proposed sites (22, 27 and 17), drillings were carried out following the In2Guide sequence until the final drill was reached.

Implant installation

All implants were installed through the sleeves at the preoperatively planned sites while the computer-guided stent was fixed in the patient's mouth (Figure 7). Following implant installation, the computer-guided stent was removed, and covering screws were placed over all implants.

Following implant installation, a postoperative CBCT was done to help determine the accuracy of the computer-guided stent using In2guide Pro Software (Figure 8).

Same-axis alignment between the post- and preoperative CBCT was achieved by superimposing the preoperative plane onto the postoperative scan using a dedicated algorithm and comparing the resulting implants in three directions of space, namely angular deviation, deviation at the implant's coronal platform, and deviation at the apical part of the implant. All measurements were taken using dedicated software (In2Guide™). Coronal and apical differences were measured in mm while angular deviation was measured in degrees (Table 1).

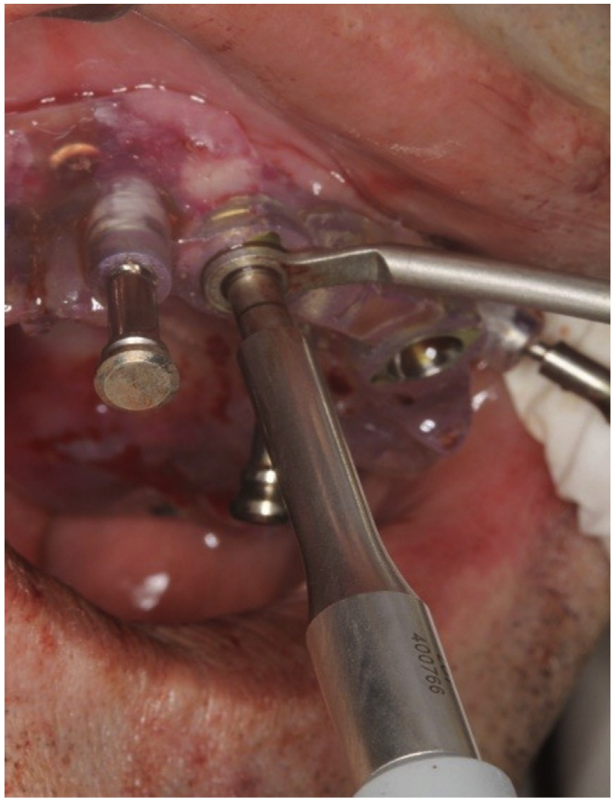

Figure 5: Osteotomes used to expand the bone through the guided stent sleeves to control expansion in these areas.

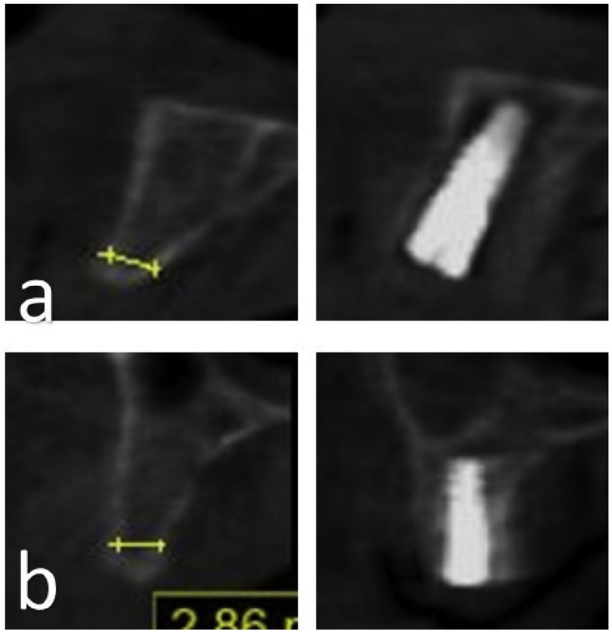

Figure 7: Before and after expansion CBCT sections, a; Implant site 12 (lateral incisor), b; Implant site 15 (premolar area).

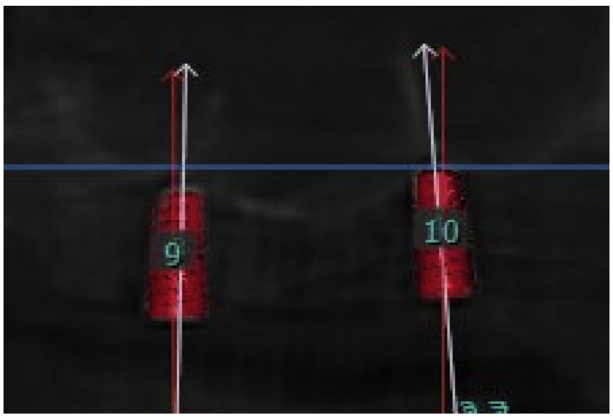

Figure 8: Superimposing the preoperative plane (red arrow) onto the postoperative scan (white arrow).

Table 1: Coronal, apical, and angular deviation of placed implants.

Implant site	Coronal deviation	Apical deviation	Angular deviation
17	0.34	0.42	1.85
15	0.65	0.73	2.8
12	0.43	0.69	1.7
22	0.91	1.04	4.2
27	0.31	0.22	2.03
Mean	0.528	0.62	2.516
SD	0.225	0.280	0.923

SD, standard deviation; implant site 17, upper right 2nd molar area; 12, upper right 2nd premolar area; 12, upper right lateral incisor area; 22, upper left lateral incisor area; and 17, upper left 2nd molar area.

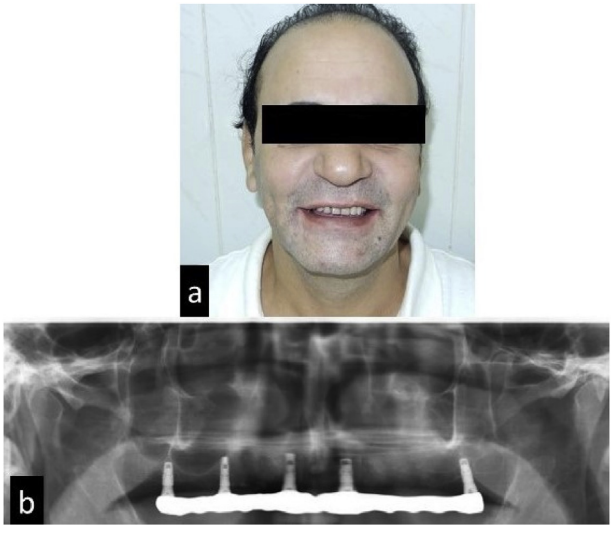

Figure 9: a; Panoramic and b; Clinical view of the finished implant-supported prosthesis at 24 months of follow-up.

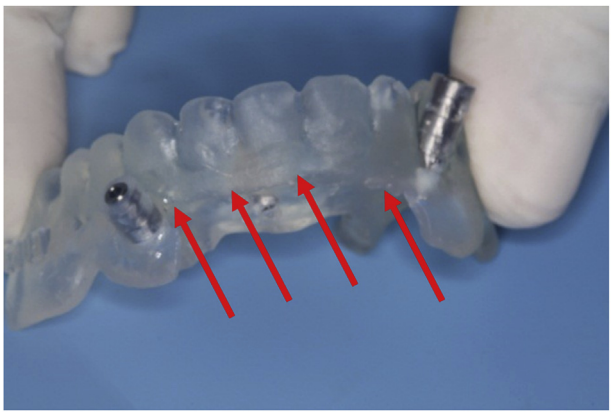

Figure 10: 3D printed surgical stent, arrows indicated the opening in the vestibular flange of the stent.

Postoperative instructions were given as usual. The patient's upper denture was relieved, and a soft liner (Acrostone, Acrostone Relining Materials) was applied to help seat the denture after implant installation.

After six months of implant placement, the classical steps of the hybrid full-arch fixed prosthesis were followed. The patient was instructed on how to maintain the health of the oral tissues, particularly the peri-implant tissues, with the aid of dental floss.

The patient followed up at one and two years of prosthesis delivery with a panoramic x-ray showing implants with bone support after 24 months of prosthesis delivery (Figure 9).

Discussion

Prosthetic-driven implant placement using a dual scan procedure optimises scanned information and serves as a reference for implant placement. Despite the numerous advantages of computer-guided (computer-fabricated) stents, their usage involves many challenges. Several precautions must be considered at all stages of the implant installation process, from the preoperative planning stage up to the installation of the implant itself.[8–10]

During the preoperative phase, the implant's width and diameter should be accurately planned to ensure that it will not endanger any of the anatomic structures. During planning for the guided stent, soft tissue thickness and metal sleeve height must be accurately calculated to guarantee correct implant installation.

In order to avoid improper seating of the surgical guide over the ridge during surgery, the stent needs to be properly fixed at the planned sites. Stent fixation with special anchor pins is very important; otherwise, implants could be placed at different sites other than those that were proposed at the preoperative planning stage.

One of the major drawbacks of computer-guided stents is difficulty in achieving and maintaining the necessary site irrigation levels during surgery. In this case report, a slight modification was made to allow for proper irrigation: a small opening in the vestibular flange of the stent was planned in order to circumvent this problem (Figure 10).

Although implant placement in the current case report was more complex given that the patient had an atrophic

maxillary ridge with compromised width that required bone expansion before implant placement, promising results have been reported, showing a mean deviation of 0.51 mm (SD, 0.22) at the coronal part of the implant, a mean deviation of 0.61 mm (SD, 0.28) at the apical apart, and a long-axis mean angular deviation of 2.51° (SD, 0.92). When these values were compared with those obtained from human cadaver studies, better results could be found *in vivo*. A recent laboratory study reported that a mean angular deviation of 3.388 ± 1.647 mm was achieved for a fully-guided implant.[14]

At the previously mentioned implant sites, extreme care was taken during the bone expansion step. The expansion procedure was carried out slowly as opposed to rapidly to avoid fracturing the buccal bone plate. Since there was a degree of resistance, the ridge was allowed to spread for 30–60 s with the osteotome left in place prior to the use of an osteotome that was one size larger. It is important to leave the osteotome in place for approximately 1 min to allow for bone flexure during simultaneous compression of the buccal and palatal bone plates.[15,16] This is crucial because the bone needs time to accommodate expansion. Tactile sensation is an essential part of the ridge expansion process, particularly during the insertion of an osteotome that is one size larger.[16]

It was found that the deviation values that were obtained for this case were lower in comparison to the results of Schneider et al.'s[17] recently published systematic review. Pooling the results of three clinical trials that included a total of 155 implant sites, the authors found a mean deviation of 1.16 mm at the entry point and 1.96 mm at the apex, and a mean angulation error of 5.73°.

The failure of the previous upper fixed implant-supported prostheses with two implants installed at the first premolar areas may be attributed to using only two implants to support a twelve-tooth cement-retained prosthesis since the excessive load gained from bilateral cantilever results in biological and mechanical complications, contributing to eventual prosthesis failure.

As such, for this case, precautions were taken during planning to reduce the likelihood of prosthesis failure. A hybrid implant-supported prosthesis was chosen because there was severe alveolar bone resorption with loss of lip support. Given the 18 mm of prosthesis height space, the use of a metal framework with acrylic resin compensated for this problem and yielded an aesthetically-pleasing result. Moreover, to decrease the load on the implants, the following measures were taken: multiple implants were used to decrease load per unit area, acrylic teeth were used as they are known to have shock-absorbing properties, teeth with a narrow occlusal table and less cusp inclines were used, and a cantilevered prosthesis was avoided. Furthermore, the patient was instructed to clean the prosthesis properly using a toothbrush and a water pick device. Use of the latter was also demonstrated for cleaning underneath the prosthesis.

Oral hygiene motivation together with controlling the overloading factor resulted in the survival of all the placed implants with good success criteria at the end of 24 months of follow up. The level of accuracy that was achieved in the current clinical report can be attributed to the use of fully-guided implant site predation, guided bone expansion, and guided implant placement.

Conclusion

Based on the results of this case report, a non-invasive approach was done via fully computer-guided implant site expansion and implant placement at the maxilla's severely atrophic site. This has produced predictable results and can be used for patients whose medical or financial conditions constrain the improvement of implant site volume through grafting procedures. However, a definite conclusion cannot be drawn from case reports, and further randomized control trials with large sample sizes should be carried out to reach sound conclusions.

Source of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The study was self funded.

Conflict of interest

There is no conflict of interest.

Ethical approval

The research ethics committee of the College of Dentistry Cairo University, approved this case report in agreement with the guidelines of the Helsinki Declaration as revised in 1975.

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How to cite this article: Alqutaibi AY. CAD-CAM surgically-guided oral implant site expansion and implant placement in severely atrophic maxilla. J Taibah Univ Med Sc 2020;15(2):153–159.