Original Article
Effect of DSR-based internal sinus floor elevation with implantation on atrophic maxilla

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Received July 6, 2017; Accepted December 13, 2017; Epub January 15, 2018; Published January 30, 2018

Abstract: This study examined natural occlusion due to atrophic maxilla using a disc-up sinus reamer (DSR). The enrollment criterion was a vertical height of residual bone < 5 mm, as measured using X-ray and CBCT. Totally, 28 patients aged 42-75 years were accepted from December 2013 to 2016. A total of 41 internal sinus floor elevation procedures were performed using DSR-based implantation, which was followed by radiographic assessment, clinical examination, safety evaluation, and pain assessment. The estimated healing time for success of the submerged implants was 6-9 months, which also included temporal and terminal prosthesis rehabilitation. Patients were followed up at 3-month intervals for up to 24 months due to the acquired height of the endo-sinus bone and natural remodeling of the microstructure as shown on X-ray (CBCT). The mean final acquired height was 8.63 ± 1.08 mm; one (3.03%) perforation occurred. A significant survival rate of 97.56% was observed compared to other reported approaches of sinus floor lifting. The average pain index was 0.82, which was much lower than previous studies. Temporary reduction of the alveolar bone was observed during the first 3 months (P < 0.05), but remodeling stabilized after 6 months. More importantly, complications such as peri-implant infection and sinusitis did not occur when physical and radiography diagnosis were used. DSR-based sinus floor elevation with implantation combined in severely atrophic maxilla extends the implications for edentulous repair. In conclusion, the procedure is safer and less invasive.

Keywords: DSR-based implantation, disc-up sinus reamer, maxillary sinus floor elevation, atrophic maxilla

Introduction

An atrophic maxilla, with reduced volume of the alveolar crest and sinus pneumatization, limits the implications of dental implantation due to the shortage of bone between the sinus floor and the ridge of the alveolar crest [1, 2]. Lateral sinus floor elevation (LSFE), first described in 1980, adopted a window opening to the lateral maxillary wall, which provided direct space for sinus membrane lifting and graft placement after inside manipulation [3]. With some optimization, it is still generally widely accepted that this approach presents credible long-term outcomes and meets a clinical need for implantation [4-6]. Despite the progress on edentulous repair in recent years, significant challenges remain. First, membrane perforation is not an unavoidable complication that leads to implantation failure [7]. Second, pain and swelling associated with the invasive procedure increase the possibility of noncompliance and anxiety in patients.

Alternatively, osteotome sinus floor elevation (OSFE), introduced by Tatum in 1986 and by Summers in 1994, induces a green fracture of the sinus floor, which facilitates grafting with transalveolar delivery of materials by tapping [8-12]. According to a series of studies, the OSFE technique is an acceptable alternative with an enlarged selection of implants and related grafts [13-17]. In general, the OSFE has only been used in patients with a vertical bone height of 5 mm or greater. When the residual bone height (RBH) is less than 4 mm, delayed
implant placement is strongly recommended [18]. In contrast, recent studies have extended the indication of OSFE. The survival rate reached 85.7% in 1999, followed by 95.5% in another study; the RBH was 4 or 1-2 mm [13, 19]. Additionally, Teng et al. and Chen et al. both achieved a 100% survival rate by applying a modified OSFE technique in short-term studies, with a mean RBH of 3.34 and 3.23 mm, respectively [20, 21]. In summary, no surgery can be performed without tapping upwards to the sinus floor during the osteotome, which may cause head vibrations and benign positional paroxysmal vertigo (BPPV) [22-25]. Moreover, it is difficult to verify the certainty of membrane perforations during sinus elevation due to incomplete visualization. In cases of membrane perforation, the occurrence can be remedied by LSFE or delayed surgery, which causes secondary trauma and requires a longer healing time.

In the current study, a disc-up sinus reamer (DSR) was designed for bone restoration during sinus floor elevation combined with simultaneous implant placement using the transalveolar approach. DSR-based implantation was considered to be less invasive and safer, while the traditional OSFE technique using a mallet and chisel often resulted in some discomfort. This work used CBCT monitoring of acquired bone tissue remodeling to optimize DSR-based sinus floor elevation and was expected to provide researchers and clinicians with validated outcomes of implantation, which would clarify dental rehabilitation of the atrophic maxilla and have extended implications.

Material and methods

Subjects

The study design and clinical procedures used were developed with the approval of the institution review by the Ethics Committee and patient consent, in accordance with the World Medical Association Declaration of Helsinki, 2008. All patients received sinus floor elevation using DSR-based implantation, which was conducted to treat an atrophic maxilla. Between December 2013 and December 2016, 28 consecutive patients (12 men and 16 women) aged 57 ± 7.59 years were included.

The clinical criteria of enrollment included: unilateral or bilateral edentulous posterior maxilla (RBH range: 1-5 mm), no systematic disease (such as heart disease or diabetes) or untreated sinusitis or periodontitis, and normal occlusion.

Instruments and equipment

A disc-up sinus reamer (Medical Instrument Systems Co., Ltd., Korea), Planter Osseocision (Biomet 3i, USA), Dentis Implant System (DENTIS Co., Ltd., Korea), NobelReplace® Implant

Figure 1. Illustrations of the overall surgical procedure. (A) Reflection of the edentulous posterior maxilla; (B) Flap reflection and marking with a 2-mm round drill at the 15 site and (C) at the 17 site; (D) Site preparation with a 2.2-mm pilot drill; (E) A depth of 1 mm below the sinus floor; (F) Cutting off the residual sinus floor with a DSR at the 15 site and (G) the 17 site; (H) Disk-like bone fragment; (I) Bone grafting; (J) Sinus floor elevation with a DSR; (K and L) Implants installation.
System (Nobel Biocare AB, Sweden), Ankylos® Implant System (DENTSPLY Implants Manufacturing GmbH, Germany), Bio-Oss® (Geistlich Pharma AG, Switzerland), and CS 9300 System (Carestream Health, Inc., USA) were used in this study.

**Experimental procedures**

Atrophy maxilla wax-up and implant plate: In the pretreatment stage, a diagnostic wax-up was used to visualize the results of a prosthetic case prior to treatment. In particular, an implant template manufactured according to the protocol was used to reconstruct the morphological outline and confirm the implantation site of the edentulous spaces. We used radiographs, cone beam computed tomography (CBCT), and oral panoramic radiographs (Carestream Health, Inc., USA) to optimize the implant site between the sinus floor and the edge of the alveolar crest. Moreover, cortical and cancellous bone were scaled according to density using panoramic screening.

**DSR-based implantation and sinus elevation:** As a prophylactic against infection, 0.5 g of amoxicillin was administered 1 hour before surgery, followed by a 1-min oral rinse with 0.12% chlorhexidine gluconate prior to sinus elevation.

The overall process of implantation is illustrated in **Figure 1**. After administration of local anesthesia, an incision along the alveolar ridge made the edentulous space completely visible using full-thickness flap reflection. We proposed the initial implant preparation and drilled 1 mm in depth and 2 mm in diameter, followed by 2.2 mm in diameter, to guide the procedure. The drilling approximated 1 mm residual height of the sinus floor, which was also based on the RBH on the radiograph. The variants of anatomical morphology of the sinus floor are listed below:

1. **Flatten residual pattern:** the sinus floor beyond the implant site was flatter and had a higher bone density. Twist drills were used in osteotomy to enlarge the holes to pre-implant status: 1.0-1.5 mm less than the diameter of the implant. A DSR was selected to calibrate the diameter, corresponding to that made by the twist drill. Gentle force was used to cut off the residual sinus floor into a disk-like bone plate. The DSR procedure was performed at 50 rpm without saline irrigation; other procedures were performed at 1200 rpm. Autogenous bone chips were collected during the drilling process. A sudden decrease of resistance occurred when the bone plate was formed. Special attention was paid to avoid sinus membrane perforation. The integrity of the sinus membrane was usually inspected by closed visual inspection and/or the Valsalva maneuver, while the drilling depth could be gauged simultaneously. Building on the drilled space, materials (a mixture of Bio-Oss and autogenous bone in saline) were moderately placed using a blunt-ended condenser toward the apex 2 mm past the RBH, and using the DSR at 20 rpm. The disc-like plate was maintained on the graft, preventing contact between the DSR and the membrane. The graft placement was duplicated and/or triplicated to reach the expected height set by the gauge of the DSR, and the submerged implant was visible throughout the healing period (**Figure 2**).

2. **Sinus floor with septum or tilted:** we applied the DSR (2.5 mm diameter) at 50 rpm without saline irrigation during osteotomy. After confirming that no perforation had occurred, we drafted a mixture of materials 2 mm beyond the RBH at 20 rpm. It achieved a size 1.0-1.5 mm smaller than the expected diameter after a series of enlargements with the DSR. Meanwhile, the DSR was also used to acquire the height necessary for installation and implantation (**Figure 3**).
Due to the concern of perforation, the treatment was re-planned using LSFE. Additionally, the submerged approach was preferred for all implants due to healing convenience.

Postoperative treatment

All patients were prescribed antibiotics (0.5 g amoxicillin three to four times per day and 0.5 g ornidazole twice per day for 5-7 days) and a mouth rinse of chlorhexidine (24 hours after DSR implantation, twice per day for 2 weeks) to prevent intraoral infection. Sutures were removed on the seventh day. The time required for healing was 6-9 months, adjusted according to the physical status and abutment connection. The occlusion restored with temporary crowns lasted 3 months, then the permanent prostheses were inserted.

Implantation radiography and pain evaluation

Follow-up recalls were scheduled for the first, third, sixth, and twelfth month during the first year. The follow-up period for each case was an average of 17.41 ± 6.38 months (range: 3-24 months). In each scenario, we used both CBCT and panoramic radiography to measure the endo-sinus bone residual and shape. We also checked (i) endo-sinus bone height, (ii) infections associated with implantation, (iii) osseointegration of the implants, and (iv) pain or noncompliance.

Postoperative pain was estimated using a visual analogue scale (VAS) and recorded as a number (0-10, where 0 indicated “no pain” and 10 indicated “worst pain possible”) [26].

Radiographic measurements were similar to the methods used by Teng et al. The RBH average equation, \( RBH = \frac{1}{3} (M+C+D) \), was applied; M, C, and D were derived separately from the mesial, central, and distal sites of the residual alveolus. The alveolar bone height immediately after surgery (ASBH), ABH1 (third month), ABH2 (sixth month), and ABH3 (twelfth month) were calculated. The vertical bone gain (VBG) was calculated using the equation \( VBG = ASBH - RBH \).

To test the volume of bone at each stage and the infection status, the vertical bone was calculated using the clinical criteria VBL1 = ASBH-ABH1, including VBL2 (sixth month) and VBL3 (twelfth month), defined using the equations VBL2 = ASBH-ABH2 and VBL3 = ASBH-ABH3, respectively. Follow-ups and radiographic measurements were conducted by two independent observers.

Statistical analysis

Descriptive statistics were used to analyze patient data, including sex, age, follow-up, pain index, and implantation, presented by site, system, diameter, length, and radiography. We analyzed the demography parameters applied to the cohort using the mean values ± standard deviations. The ABH and VBL during follow-up were documented and estimated with a nominal two-sided ANOVA, with a default P value of < 0.05. All analyses were performed using IBM SPSS Statistics for Windows, Version 19 (IBM Corp., Armonk, NY, USA).

Results

In our cohort, 41 implants were placed for 28 patients. The mean RBH was 3.49 ± 0.81 mm (range: 1.67-4.89 mm). Each implantation met the criteria, stability, and osseointegration tests. The survival rate of the implants was 97.56%. Complications such as peri-implant infection or sinusitis were not observed, but there was one case of perforation (3.03%, 1/41 implants). Five of 41 implants without perma-
# Table 1. Variables and results of 41 implants during the study period

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Average: 57.68

M, male; F, female; RBH, residual bone height before surgery; ASBH, bone height after surgery; VBG, vertical bone gain after surgery; ABH1, alveolar bone height at 3-month recall; VBL1, vertical bone loss after 3 months; ABH2, alveolar bone height at 6-month follow-up; VBL2, vertical bone loss after 6 months; ABH3, alveolar bone height at 1-year follow-up; VBL3, vertical bone loss after 1 year. ‘/’, one perforation occurred during surgery. In two patients, the final prosthesis was not restored until after data collection had finished.
nent prostheses were excluded from the on-treatment group to minimize the impact of chewing function (Table 1).

The median of VAS score was 0. Twenty-eight patients in three subsets were scored; 10 varied between 0-3 and one reported a score of 4-6. One case reported temporomandibular joint fatigue due to mouth opening. Moreover, no patient experienced any postoperative BPPV or disorientation (Table 2).

Radiography revealed that the mean ABH was 12.12 ± 0.86 mm and the endo-sinus bone yield was 8.63 ± 1.08 mm. Three months postoperatively, the alveolar bone height had not attained the initial height, but had decreased to 11.46 ± 0.85 mm, indicating a loss of 0.66 ± 0.33 mm during the first 3 months. In contrast, the ABH at 6 and 12 months (11.14 ± 0.9 and 11.11 ± 0.90 mm, respectively) showed a platform compared to the height three months after surgery (p < 0.05, two-sided ANOVA, Figure 4). Bone remodeling significantly stabilized between 6 and 12 months (p = 0.791), although significant bone loss presented in the early stage of treatment (Figure 5). A case with illustrations is shown in Figure 6.

Discussion

In the follow-up of DSR-based implantation and permanent outcomes, we found an augmented transverse form around the endo-sinus floor in the initial RBH. The procedure had a survival rate of up to 97.56%.

The results were closely related to the structure of the specially designed drill. The DSR, an antidirection twist drill in which the apical part is a disc-like concave surface, is characterized by three cutting edges: the sharp edge, side edge, and twisted edge (Figure 7). The sharp edge is a point edge, while the side edge and twisted edge intersect at the top. As described in our preclinical study, the elevated floor was cut into a disc-like bone plate using the sharp edges. Importantly, during advancement, the sinus membrane was gradually elevated and separated by the disc derived by the sharp edges, suggesting that the sinus membrane can be protected. Furthermore, the drilling handle of the DSR could be installed on the handpiece of a divested implant system, setting the rotate speed and torque in a controlled pattern. Hence, the controlled, constant forces of the DSR may reduce the blindness of the surgery and the risk of perforation. The perforation caused by the DSR in 33 maxillary sinuses was 3.03%, compared to 11.1% (2/18) in modified OSFE therapy.

The thread of the twisted edge has a reversed rotation in contrast to a traditional twisted drill,
which is the most unusual feature of the DSR. The mechanism of the twisted edge is similar to that of a low-speed auger conveyor. During the drilling process, the scraped bone debris can be collected and conveyed to the bottom of the maxillary sinus floor by the twisted edge at 20 rpm, rather than removed from the osteotomy site. Therefore, more autogenous bone is preserved. Because of this feature, no additional artificial bone is required during the elevation procedure when the elevated bone height is less than 3 mm.

In our study, the average endo-sinus bone gain was $8.63 \pm 1.08$ mm, which indicates that the elevation heights were greater than 3 mm. In such clinical situations, graft materials with saline were added to the osteotomy site and conveyed to the bottom of the sinus floor using the twisted edge. By mixing the graft and bone debris, the coagulum was formed beneath the disc-like bone plate and the sinus membrane and served as a cushion to reduce the compressive force delivered by the DSR. Meanwhile, the three-sided edge extending upward and outward from the central axis formed a concave surface on the top. With balanced pressure, the coagulum was gently distributed within a volume proportional to the membrane shape, and tension was assigned smoothly. Even in cases of septum or tilted floor, the sinus membrane can reach the required height without damage. This is the reason the mean elevation height of our study surpassed the highest elevation (6-7 mm) reported by Calvo-Guirado et al. [27] using OSFE. Notably, the highest elevation height we attained was 10.41 mm; accordingly, the implants were approximately 10 mm in length. This result was consistent with our preclinical trial. In closing, there are no elevation limits on residual height in DSR-based sinus floor elevation and implantation within the scope of clinical needs.

Compared with the LSFE and OSFE reported previously, the DSR utilizing a transalveolar pathway avoided window in the lateral wall. Thus, the surgical-derived trauma, complications and patient incompliance were reduced to a low level. Notably, despite the compromised mouth opening in osteotomy, the DSR in the
second molar was manipulated directly and resulted in a low pain index, indicating that most patients considered the procedure to be acceptable. In contrast, more than 23% of patients receiving OSFE considered the technique to be unacceptable. The DSR sinus floor elevation technique was estimated to be a substitute technique with fewer invasions and increased acceptance [28].

Although it is conceivable that the DSR-based sinus floor elevation and implantation resulted in augmented RBH and moderate VAS on an atrophic maxilla, a few factors should be determined. First, efforts have been made to increase the primary stability of the implants. However, all surgeries used the undersized technique, which means the diameter of the last DSR is one size (1.0-1.5 mm) smaller than the implant diameter [29]. Implant design is another factor in the reinforcement of implant primary stability [30]. Accordingly, the implant with a tapered shape, surface roughness, and fine threads in the neck was selected [31-33]. Second, in our cohort, submerged healing was the preferred method for implant placement to avoid infection and trauma derived from oral hygiene and occlusion. Lastly, the healing time necessary for osseointegration before permanent prostheses was 6-9 months. Moreover, our data support the idea that the reduction of the bone-derived draft in the early stage (6 months of treatment) shifted to the stable stage (after 6 months of treatment) not only in transplant surgery, but also in sinus floor elevation, as indicated by the alveolar bone surrounding the apex of the implant. The process of bone remodeling was consistent with the results observed in other studies, but each contained a number of patients with an RBH of greater than 5 mm [34-36].

This study highlighted that the utility of DSR-based sinus floor elevation and implantation impacting the atrophic maxilla, with maximum space for coagulum by mixed sheared bone and biomaterials, showed a stable status for bone remodeling and implant submerging. In contrast to previously reported techniques, DSR-based therapy has extended implications for the prediction of RBH (8.63 mm in the retro molar area) and ABH (12.12 mm) at the end of the follow-up period. Finally, DSR-based therapy showed an acceptance with quantified pain scales, suggesting that LSFE-derived noncompliance was eliminated. Thus, our findings associated with DSR-based implantation and elevation advanced the novelization in our cohort and may require further validation in independent cohorts.

Acknowledgements

This work was supported by the Natural Science Foundation of Shandong Province, China (Grant No. ZR2010HM036).

Disclosure of conflict of interest

None.

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References

DSR-based internal sinus floor elevation


