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Transcrestal Sinus Floor Elevation with Simultaneous Implant Placement: A Case Series

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Abstract:
Background: Implant placement in the posterior maxilla can be a challenging procedure due to the reduced quantity and relatively low quality of bone below the maxillary sinus. The aim of this case series was to demonstrate the process and the outcome of transcrestal sinus floor elevation with simultaneous implant placement.

Materials and methods: Four patients were treated with five implants placed using the bone-added osteotome sinus floor elevation (BAOSFE) advocated by Summers. Surgical considerations including interarch relationship, width of alveolar crest, vertical bone height, and sinus floor anatomy were evaluated. Treatment of these sites involved flap reflection, osteotomy with BAOSFE, implant placement, and guided bone regeneration if needed. Clinical parameters and radiographic examinations were evaluated at baseline and postoperatively.

Results: All implants survived throughout the follow-up period of 1–5 years. The alveolar bone height of these sites was successfully gained. Dome-shaped graft materials were noted surrounding implant apex, and bone remodeling was noted in the course of the time. Complications like benign paroxysmal positional vertigo (BPPV) were encountered episodically.

Conclusion: Transcrestal sinus floor elevation with simultaneous implant placement and guided bone regeneration may yield successful outcomes. Osteotome instruments optimize and facilitate dental implant placement in posterior maxilla in terms of bone condensation and sinus floor elevation. Several parameters should be evaluated for choosing the surgical techniques.

Implant placement in the posterior maxilla can be a challenging procedure due to the reduced quantity and relatively low quality of bone below the maxillary sinus. Tooth extraction and pneumatization of the maxillary sinus result in a reduced width and height of alveolar bone[1]. Type III and IV[2–4] soft bone are often encountered at the posterior maxilla region. Thus, different techniques have been proposed to augment the bone volume, as well as to increase the density of bone to facilitate implant placement.

Sinus floor elevation is widely used in the contemporary implant treatment to increase the residual bone height[5,6]. A lateral approach is generally indicated in cases of less than 4–5 mm of residual bone. The transcrestal approach is an alternative[7], especially when a greater height of bone is available. Transcrestal sinus floor elevation was first introduced by Tatum[8] and then modified by Summers[9–12]. Tatum used "socket formers" corresponding to different sizes of implants. After greenstick fracturing the sinus floor by vertical taps, "S sinus implants" were placed. Summers used a set of osteotomes of different diameters to prepare the implant site and increase the bone density at the same time. The bone-added osteotome sinus floor elevation (BAOSFE), which involves pressure through the bone mix and trapped fluids onto the sinus floor, was proposed and proved to be safe and effective[13]. Many studies[14–21] have shown that varying graft materials should be used to maintain the space below the elevated sinus floor, and high implant survival rates were reported using osteotome sinus floor elevation with simultaneous grafting[22,23]. The osteogenic activation after sinus floor minifracture and the osteogenic activity of the sinus membrane may contribute to endo-sinus bone formation[24]. Although osteotome sinus floor elevation with and without grafting were both predictable in the short-term[25–29], more bone height was gained when graft material was used[30].

Guided bone regeneration (GBR) is a therapeutic procedure aiming to achieve regeneration of osseous defects via the application of barrier membranes. Dahlin et al.[31,32] provided evidence that GBR is effective in promoting peri-implant bone formation around exposed threads of implants with the application of e-PTFE membranes. Further controlled clinical studies[33] and case series[34–36] confirmed that GBR may promote bone formation in dehiscences and fenestrations around one- and two-stage implants. There is also histological evidence supporting vertical bone augmentation combined with implant placement using the GBR principle[37,38]. Given the appropriate management, GBR therapy has demonstrated a high degree of predictability and success[39–41].

While clinicians continue to develop several modifications to the original protocol, little information was given on the comprehensive consideration of cases in which transcrestal sinus floor elevation and GBR are indicated. The aim of this case series was to demonstrate the process and the outcome of transcrestal sinus floor elevation with simultaneous implant placement and GBR if necessary.

Materials and methods

Four subjects (three women and one man, with a mean age of 57 years) referred to the Division of Periodontics, Department of Dentistry of National Taiwan University Hospital for implant treatment were included in the study. All four patients underwent unilateral sinus surgery. The presurgical evaluation consisting of clinical examination and radiographic analysis of the edentulous posterior maxilla with cone–beam computed tomography (CBCT). Surgical considerations including interarch relationship, width of alveolar crest, vertical bone height, and sinus floor anatomy were evaluated.

Inclusion criteria

Patients asking for implant treatment in the posterior maxilla were included in the study if the general health conditions allowed surgical procedures. No pathological changes in radiographic and clinical examinations were noted.

Exclusion criteria

Patients with smoking habits and pathology of maxillary sinus were excluded. If the primary stability of the implant in the residual bone was not possible, the patient was also excluded.

Surgical procedure

The surgical procedure was performed with the patient under local anesthesia. With a midcrestal incision and sulcular incisions of adjacent teeth, mucoperiosteal flaps were reflected. To secure proper alignment of the implants, surgical stents were used. A pilot drilling and initial osteotomy were followed by preparation of the implant site with osteotomes of increasing diameter. Osteotomy was performed to within 1–2 mm of the sinus boundary. The tips of the osteotomes were concave. The initial osteotome was gently inserted with hand pressure or light malleting to a depth 1 mm short of the residual bone height. Larger-diameter osteotomes were subsequently inserted with lateral condensation on the spongious bone to increase the bone density. Drilling may be required when denser bone was encountered. With the final osteotome, transcrestal sinus floor elevation was performed. The cortical plate was punched out of the sinus floor with adherent Schneiderian membrane and a tent-like formation was created. For the BAOSFE, portions of demineralized bovine bone mineral (DBBM) particles (Bio-Oss, Geistlich Pharma AG, Switzerland) were applied consecutively with light malleting because bone substitutes alone showed a trend of better result[42]. When defects were noted at osteotomy sites and GBR was indicated, decortication was performed around the defects. Autogenous bone chips were harvested with a bone scraper (Micross, Divisione Medicale Meta, Italy). Collagen membrane (Bio-Gide, Geistlich Pharma AG, Switzerland) was trimmed and DBBM particles were prepared as well for GBR procedure. The largest osteotome was reinserted to position the graft material in the newly formed space between the sinus membrane and the sinus floor, then implants were placed. In the case where GBR was not indicated, transmucosal healing of the implant was obtained. In three cases of the study, GBR was performed following Buser's protocol[43] with the first layer of autogenous bone onto the exposed threads of implants and the second layer of DBBM to augment the ridge. After collagen membrane coverage, implants were submerged, and second stage surgeries were performed after six months with apically positioned flap or free keratinized mucosal grafting.

Prosthetic treatment

The prosthodontic procedure was carried out by specialists in the Division of Prosthodontics of National Taiwan University Hospital. In all cases, temporary acrylic crowns were used during the first 1–3 months following abutment connection, serving as a scaffold to mold soft tissue contour and as a diagnostic template for the final restoration. Implant stability was checked manually and by use of an abutment screwdriver when the permanent prosthetic rehabilitation was initiated. Careful occlusal adjustment was made to exclude excess loading of the implants.

Results

Five dental implants were placed into edentulous sites of four patients (Tables 1 & 2). According to preoperative evaluation (Figs. 1–4), the width of alveolar crest ranged from 5 to 9 mm (mean value 7 mm). In cases 2 and 3, horizontal GBR was indicated due to the limited width of the alveolar crest. In case 4, ridge contour discrepancy was noted distally at the left second molar edentulous area. The implant was placed slightly supracrestally, using the neighboring implant platform as a reference level, and vertical GBR was performed. The preoperative vertical bone height ranged from 4.7 to 8.7 mm (mean height 6.9 mm). The increase in the height of the implant sites by the BAOSFE procedure was 2 to 5 mm (mean height 3.6 mm). Valsalva maneuver was negative for all cases. After sinus floor elevation, rough-surfaced implants of 8 to 10 mm in length could be placed (mean length 9.4 mm). They were significantly larger than the residual vertical bone height at the implant sites. The distance between implant apex and sinus floor were gradually becoming shorter, suggesting a bone remodeling process[44] below the sinus floor. The BAOSFE procedure in the case series produced two episodic complications (cases 2 & 4), both noted postoperatively. All implants survived following from 1 to 5 years.

Discussion

When implant therapy is planned in the atrophic posterior maxilla, there are several considerations for an appropri-

Table 1 Preoperative data

Case	Age	Sex	Implant position	Interarch relationship (mm)	Vertical bone height (mm)	Width of alveolar crest (mm)	Sinus floor anatomy
1	39	F	Right first molar	12	8.7	7	Flat
2	63	F	Right first premolar	9	7.2	5	Oblique
3	69	M	Left first premolar	9	7.3	5	Oblique
4	57	F	Left first molar	10	6.6	9	Flat
			Left second molar	12	4.7	9	

Table 2 Intraoperative and follow-up data

Case	Type of implants	Implant diameter (mm)	Implant length (mm)	Elevation (mm)	Sinus graft material	GBR	GBR graft material	Stages	Specific complications
1	Straumann	4.1	10	4	DBBM	N/A	N/A	One	No serious complications
2	Straumann	4.1	10	2-4	DBBM	H*	A*+DBBM	Two	Sinus membrane perforation
3	AstraTech	3.5	9	3-5	DBBM	H	A+DBBM	Two	No serious complications
4	Straumann	4.8	10	3	DBBM	V*	A+DBBM	Two	BPPV*
		4.8	8	4					

* H=horizontal, V=vertical, A=autogenous bone chips harvested from surrounding alveolar ridge, BPPV=benign paroxysmal positional vertigo

Fig 1. Case 1

(A): Pre-operative panoramic radiograph showed favorable interarch relationship and flat sinus floor.
(B): Pre-operative CBCT images showed limited vertical bone height (8.7mm) and favorable width of alveolar crest (7mm).
(C): Radiograph obtained immediately after implant placement.
(D): Radiograph obtained 12 months post-operatively.
(E)(F)(G) Clinical photos of occlusal, buccal and palatal aspects before reconstruction.
(H)(I)(J) Clinical photos of occlusal, buccal and palatal aspects after reconstruction.

Fig 2. Case 2

(A): Pre-operative panoramic radiograph showed favorable interarch relationship and oblique sinus floor.
(B): Pre-operative CBCT images and radiograph showed limited vertical bone height (7.2mm) and limited width of alveolar crest (5mm).
(C): Pre-operative periapical radiograph showed even less sufficient vertical bone height due to the coronal defect distal to the planned implant axis.
(D): Radiograph obtained immediately after implant surgery.
(E): Radiograph obtained 6 months post-operatively.
(F): Radiograph obtained 12 months post-operatively.
(G)(H)(I) Clinical photos of occlusal, buccal and palatal aspects before reconstruction.
(J)(K)(L) Clinical photos of occlusal, buccal and palatal aspects after reconstruction.

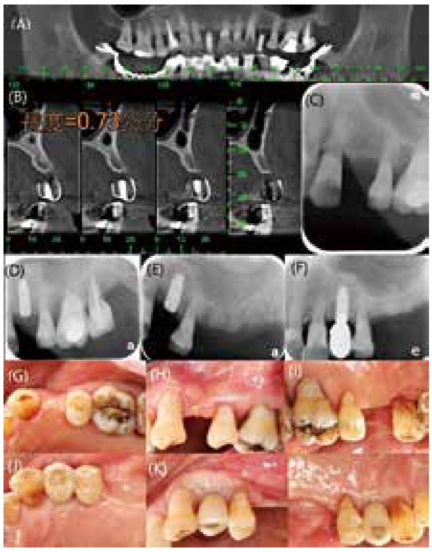

Fig3. Case 3

(A): Pre-operative panoramic radiograph showed favorable interarch relationship and oblique sinus floor.
(B): Pre-operative CBCT images showed limited vertical bone height (7.3mm) and limited width of alveolar crest (5mm).
(C): Pre-operative periapical radiograph showed oblique sinus floor.
(D): Radiograph obtained immediately after implant surgery.
(E): Radiograph obtained 6 months post-operatively.
(F): Radiograph obtained 12 months post-operatively.
(G)(H)(I) Clinical photos of occlusal, buccal and palatal aspects before reconstruction.
(J)(K)(L) Clinical photos of occlusal, buccal and palatal aspects after reconstruction.

ate diagnosis and treatment plan:

- The interarch relationship is the preliminary parameter for prosthetic driven implant therapy. It is evaluated with a diagnostic wax-up, and a surgical stent with a radiopaque marker could be fabricated. Unfavorable interarch conditions may need resective or regenerative procedures of the ridge, or proper management of the opposing teeth.
- Vertical bone height is of primary importance in sinus floor elevation cases. Residual bone height less than 4 mm is associated with reduced primary implant stability[45,46], which necessitates a staged approach to implant therapy. One of the drawbacks of transcrestal sinus floor elevation is the limited increase in bone height. Summers suggested that BAOSFE should be considered for patients with 5 mm or more bone remaining beneath the floor of the sinus. Otherwise, the conventional lateral window technique should be considered.
- The width of the alveolar crest, together with the planned implant position and implant diameter, determine the need for horizontal GBR. In most cases, peri-implant craterlike bone defects were rather small in volume, and GBR with simultaneous implant placement can be planned, as in cases 2 & 3. If there were severe defects and implant primary stability could not be obtained with the residual width of the alveolar crest, a staged approach was then indicated.
- Sinus floor anatomy, whether flat or oblique, is another factor to be considered. Transcrestal sinus floor

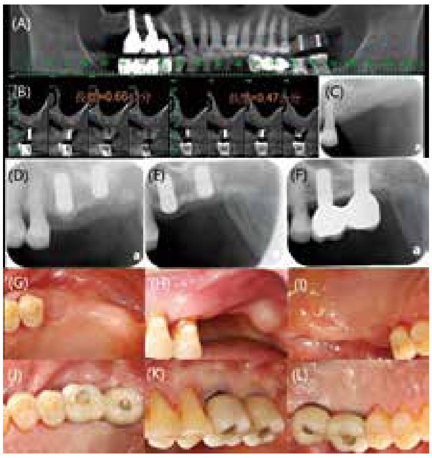

Fig 4. Case 4

(A): Pre-operative panoramic radiograph showed favorable interarch relationship and moderately flat sinus floor.

(B): Pre-operative CBCT images and showed limited vertical bone height (4.7-6.6mm) and favorable width of alveolar crest (9mm).

(C): Pre-operative periapical radiograph showed flat sinus floor.

(D): Radiograph obtained immediately after implant surgery.

(E): Radiograph obtained 6 months post-operatively.

(F): Radiograph obtained 12 months post-operatively.

(G)(H)(I) Clinical photos of occlusal, buccal and palatal aspects before reconstruction.

(J)(K)(L) Clinical photos of occlusal, buccal and palatal aspects after reconstruction.

elevation at oblique sinus floor may result in higher risk of membrane perforation. A lateral window may be an alternative in that situation. However, in terms of bone remodeling and shrinkage, greater implant-intruding angle, i.e., flat sinus floor, was suggested to result in a more apparent reduction of grafted bone height after osteotome sinus floor elevation[47].

Because the transcrestal approach involves a blind elevation of the sinus floor, membrane perforation is a concern. Membrane perforation during transcrestal sinus floor elevation was the most commonly reported surgical complication, and displacement of graft material through the sinus could possibly lead to a sinusitis condition. The integrity of the sinus membrane is verified by performing the Valsalva maneuver during the surgical procedure, though the efficacy was questioned[48]. If membrane perforation occurs, the operator may revert to the lateral window technique to repair the perforation. Even though a negative Valsalva maneuver was confirmed for all cases intraoperatively, one case of perforation (case 2) has been reported here because the patient mentioned about some particles coming out of her nostrils in the first week after surgery. It has been reported that displacement of graft material through sinus membrane may cause transient or chronic sinusitis in 10–20% of sinus elevation cases, prompting the need for further treatment[49,50]. While the treatment outcome is related to the operator's experience, sinus membrane condition, and localized anatomy, using osteotomes to fracture an oblique sinus floor transcrestally will considerably increase the risk of perforating the Schneiderian membrane. Comparatively, the lateral approach is capable of augmenting large volumes of bone and can be utilized irrespective of flat or oblique sinus floor.

Transcrestal sinus floor elevation is considered a less invasive, less time-consuming, and more cost-effective procedure compared with the lateral approach[51]. Mucoperiosteal flap reflection can be reduced to a minimal extent, and only a puncture through the bony wall of canine fossa was required[52,53]. Lower morbidity is also expected in terms of postoperative swelling and pain. However, one case (case 4) encountered vertigo and a feeling of spinning the day after the surgical treatment. A consultation visit was arranged with the Otorhinolaryngology (ENT) Department of National Taiwan University Hospital, and benign paroxysmal positional vertigo (BPPV) was diagnosed. The patient was instructed to restrict her physical activity, and the symptoms were self-limiting within a few days. The most common cause of BPPV is labyrinthine concussion resulting in repositioning of otoliths[54]. Transcrestal sinus floor elevation using osteotomes could expose the patient to the minor trauma of osseous labyrinth, causing the patient to experience positional vertigo[55]. The greater extent the sinus membrane to be elevated and the more implants to be placed could both aggravate the situation. It is not known what magnitude of malleting force would result in a labyrinthine concussion. In cases requiring much malleting, especially for multiple implants, it is advisable to seek alternatives including short implants, tilted implants, and zygomatic implants.

Standard drilling protocol for implant placement involves removal of the existing bone and does not improve bone quality. Because the primary stability of implants is enhanced by improved bone density[56], osteotome techniques are thus a modification that increases success rates in areas of reduced bone quality. Animal studies have shown improved bone-to-implant contact percentage using osteotome technique compared with conventional implant placement protocol in the early healing phase[57]. However, if the bone is harder than anticipated, drills could also be utilized between osteotome applications to minimize the trauma from osteotome malleting. The BAOSFE procedure and its modifications[58–61] using drills or trephines have proven to be efficacious techniques in managing moderate vertical deficiencies in the posterior maxilla. A technique that could both conserve the maximum amount of bone and lessen the trauma to the patient would offer clinical benefits.

Conclusion

Within the limitation of the present case series with regard to subject numbers, transcrestal sinus floor elevation with simultaneous implant placement and GBR is a predictable method of gaining ridge height and width for implant placement, in which osteotome instruments play the role of bone condensation and sinus floor elevation. Surgeons conducting transcrestal sinus floor elevation have to know the complications, as well as to respect the limitations. Presurgical considerations including interarch relationship, vertical bone height, width of alveolar crest, and sinus floor anatomy should be evaluated for choosing the optimal surgical techniques.

中文摘要

背景：上顎後牙區的植牙在臨床上常會面臨上顎竇下方齒槽骨吸收以及骨密度不佳等挑戰。此系列病例報告主要在呈現穿脊式上顎竇增高術合併人工植牙手術的治療過程與結果。

方法：四位患者分別以 Summers 提出的增骨式骨鑿上顎竇增高術植入五支人工牙根。術前評估上下齒列關係、齒脊寬度、齒槽骨垂直高度以及上顎竇底部解剖形態，然後進行手術，包含翻瓣、增骨式骨鑿上顎竇增高術、人工牙根植入，必要時也進行引導骨再生術，並以臨床與放射線檢查比較術前與術後的情形。

結果：經過一至五年的後續追蹤，所有植體皆安然無恙，齒槽骨垂直高度皆成功地被提升。植體根尖處可觀察到骨粉形成的拱形隆起，且其形態會隨著時間而變化。另外，也偶遇良性陣發性位置性眩暈等併發症。

結論：穿脊式上顎竇增高術合併植牙與引導骨再生術可以得到成功的治療結果。從提高骨密度與上顎竇增高的角度來看，骨鑿的使用有利於上顎後牙區的人工牙根植入。針對臨床上許多因素的術前評估，將是選用何種術式的重要參考。

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