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Original Article

Modified maxillary sinus floor elevation via a mini-lateral window with simultaneous placement of dental implants: a clinical and radiographical study

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Abstract: This study assessed the effectiveness of modified sinus floor elevation via a mini-lateral window with simultaneous placement of implants in 20 patients with severely atrophic maxilla. Patients received mini-round-like or a mini-slot osteotomy which was done to establish an access on the lateral sinus wall for placement of bone grafts depending on the number of inserted implants and the characteristics of sinus floor. Clinical and radiographic parameters were collected. Results showed all implants were well maintained, with 100% cumulative success rate. The mean residual, immediate and 6-month postoperative augmented bone height was 3.0 ± 0.5, 13.6 ± 0.9, and 13.2 ± 0.8 mm, respectively. Intra-operative and 6-month postoperative implant stability quotient (ISQ) were 61.2 ± 3.7 and 76.8 ± 2.4, respectively. No significant differences were found in clinical outcomes between two types of window approaches. Sinus augmentation via a mini window with simultaneous placement of implants has a higher success rate, may improve clinical outcome and thus can be used as a reliable treatment for severely atrophic maxilla.

Keywords: Lateral sinus floor elevation, sinus augmentation, dental implant, vital bone, cone-beam computerized tomography

Introduction

Sinus augmentation using lateral window technique has been a predictable and popular approach in case of bone volume deficiency in the posterior maxilla for patients who require implant-based treatments [1-4]. Moreover, the placement of implants can be completed simultaneously or in later management to allow for graft maturation [5]. The opening created in the lateral window approach provides an easier access to the sinus membrane as well as good view in the surgery. The Schneiderian membrane reflection is extended by direct surgical undermining, and the wider the extent of reflection, the greater the vertical elevation height is [3, 4, 6, 7]. Typically, the lateral window size is determined by the amount of augmentation as well as the number of missing posterior teeth that should be replaced. On an average, a window with mesiodistal width and apicocoronal height of 20 and 15 mm, respectively (also called conventional window size [CWS]), is sufficient to ensure easy surgical access [8].

The success of a sinus augmentation via the lateral window technique can be determined by the incidence of surgical complications and the proportion of survived implants placed under a functional load in the bone [4]. However, the sinus augmentation with CWS is associated with certain biological complications, such as excessive bleeding, obvious postoperative swelling, pain, and membrane perforation. Additionally, this is an invasive surgery and associated with an increased risk of graft bone loss owing to the large size of the window and the low rate of vital bone formation owing to the massive cortical bone defect [9]. There is evidence showing that the lateral cortical bone wall of a sinus has high osteogenic capacity and is responsible for most of the vascular supply to a newly placed graft rather than the Schneiderian membrane [10]. Therefore, the

Table 1. Baseline characteristics and clinical outcomes of patients in this study

Patient No.	Sex	Age (yr)	Missing tooth	Window Shape	Window Size		ISQ		RBH (mm)	Imm-ABH (mm)	6 M Post-ABH (mm)
					Max H (mm)	Max W (mm)	Intra operation	6 M Post Operation			
1	F	78	15\16\17	MSW	5	12	64	78	3.1	13.3	12.8
2	F	30	26	MRLW	3.5	3.5	58	74	2.7	14.8	13.8
3R	M	23	13\14\15	MRLW	5	5	66	76	3.4	13.2	12.5
3L			23\24\25	MRLW	5	5	60	78	3.6	14.3	13.6
4	M	67	24\25\26\27	MSW	5.5	12.5	68	77	3.8	13.7	13.5
5	M	59	26\27	MSW	3.5	8.5	59	72	2.5	14.7	14.0
6	F	19	16	MRLW	4	4	60	79	2.8	13.1	13.5
7	F	69	25\26\27	MSW	4.5	11.5	62	75	3.0	12.9	13.3
8	M	44	26\27	MSW	3	8	55	76	2.8	12.3	12.0
9	M	42	16	MRLW	4	4	61	80	3.2	13.5	12.2
10R	F	33	15\16	MRLW	4.5	4.5	62	75	2.7	14.2	13.8
10L			26	MRLW	3.5	3.5	59	81	3.2	13.8	14.2
11	F	24	26	MRLW	4.5	4.5	68	78	3.7	15.1	14.5
12	M	25	15\16\17	MSW	4	11.5	65	77	3.3	13.8	13.4
13	F	25	15	MRLW	4	4	60	79	2.6	11.8	12.2
14	M	63	26\27	MSW	3	9	57	77	2.1	14.3	13.8
15	M	50	25\26\27	MSW	4.5	12	61	74	2.5	12.4	12.0
16	F	56	36\37	MSW	3.5	10	67	77	3.5	14.5	13.8
17	F	34	36	MRLW	4	4	58	75	2.9	13.9	13.5
18	M	68	16\17	MRLW	5	5	60	80	3.5	12.9	12.5
19	F	66	15\16\17	MSW	4.5	12	61	78	2.8	13.2	12.5
20	M	46	36\37	MRLW	5	5	56	73	3.5	12.6	12.0
Mean ± SD							61.2 ± 3.7	76.8 ± 2.4	3.0 ± 0.5	13.6 ± 0.9	13.2 ± 0.8

Notes: MSW: Mini-Slot Window; MRLW: Mini-Round-like Window; Max H: Maximum Height; Max W: Maximum Width; RBH: Remaining Bone Height; Imm-ABH: Immediately Postoperative Augmented Bone Height; 6 M Post-ABH: 6-month Postoperative Augmented Bone Height.

preservation of a substantial portion of the lateral bone may enhance healing and improve graft consolidation and maturation along with vital bone formation. The outcome of implants placed in sinus-grafted regions is closely related to the vital bone; the vital bone, which is directly interfaced with a considerable portion of the implant surface, plays critical roles in osseointegration and local responses to functional loading [11].

In order to reduce complications and retain more cortical bones to promote vital bone formation during this sinus augmentation via the lateral window, we introduced a modified sinus floor elevation technique via a mini-lateral window, which is either mini-round-like or mini-slot. This study was conducted to assess the effectiveness of sinus augmentation via the lateral window with simultaneous dental implant placement in 20 patients with severely atrophic maxillae.

Materials and methods

Patients

From July 2013 to September 2015, 20 patients (10 women and 10 men) aged 19-78 years (median: 46.1 years) were enrolled into this study. All patients provided written informed consent.

The inclusion criteria were as follows: (i) patients required posterior maxillary implants; (ii) there was no rhinitis or sinusitis; (iii) there was tooth extraction at least 3 months before implant surgery; (iv) the residual bone height (RBH) was ≤4 mm; and (v) there was sufficient bone width to maintain the primary stability of implants. Heavy smokers (>10 cigarettes/day) or patients with uncontrolled periodontal diseases were excluded from this study. Baseline patients' characteristics are summarized in **Table 1**.

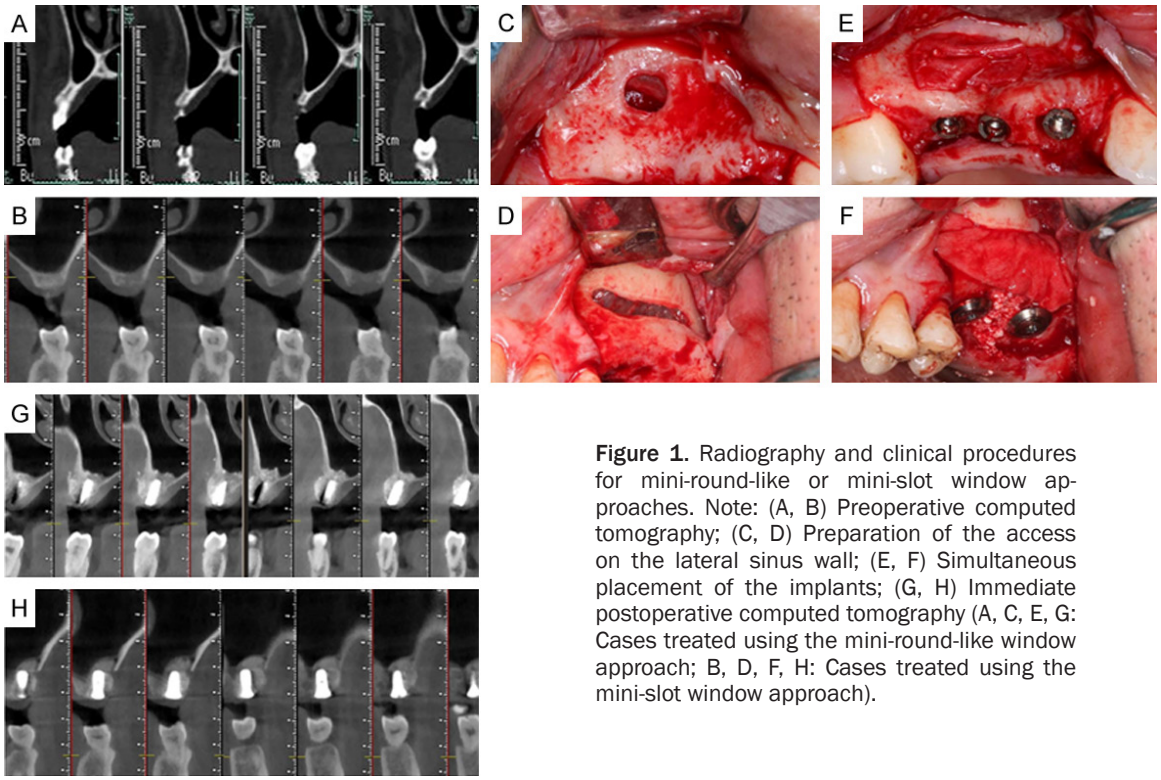

Figure 1. Radiography and clinical procedures for mini-round-like or mini-slot window approaches. Note: (A, B) Preoperative computed tomography; (C, D) Preparation of the access on the lateral sinus wall; (E, F) Simultaneous placement of the implants; (G, H) Immediate postoperative computed tomography (A, C, E, G: Cases treated using the mini-round-like window approach; B, D, F, H: Cases treated using the mini-slot window approach).

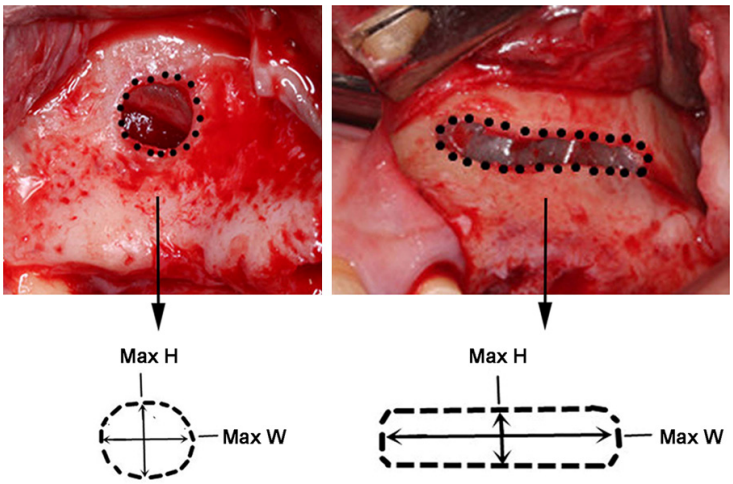

Figure 2. Measurement of approximate window size. Note: Left: Mini-round-like window; Right: Mini-slot window.

Surgical procedures

Before sinus augmentation, the number of missing teeth, height of the residual alveolar ridge, anatomy of the sinus, and position of the posterior-superior alveolar artery were precisely determined by panoramic radiography and cone-beam computerized tomography (CBCT) (**Figure 1A**, **1B**). The insertion path and shape of antrostomy were determined. Mini-round-like or mini-slot antrostomy was performed in all the patients. Local anesthesia was done with articaine and 1/100,000 epinephrine (3M ESPE-AG, Seefeld, Germany). Horizontal midcrestal and vertical releasing incisions were made to reflect a full-thickness flap. A mini-round-like or mini-slot ostectomy was performed on the lateral wall by using a high-speed, straight surgical handpiece and a mini-drill with 1-mm diameter (**Figure 1C**, **1D**). The bony wall was completely removed to gain better access. The coronal part of the window was just 3-4 mm above the sinus floor. The maximal apicocoronal height of the slot or the maximal apicocoronal height and the maximal mesiodistal width of the mini-round-like window was approximately 3-5 mm to allow the placement of elevation instruments into the sinus floor. Moreover, maximal mesiodistal width of the slot was appropriately extended to include implant placement sites. To calculate the approximate window size

(AWS), maximal height and width of the window were measured using a Hu-Friedy periodontal probe, and the value was rounded to the nearest half millimeter (**Figure 2**). The elevated Schneiderian membrane was maximally extended both mesiodistally and medially over the anticipated drilling site by using a microelevator that was specifically prepared in our department for sinus membrane reflection. Drilling was performed continually while protecting the membrane with a periosteal elevator. Then, the graft materials (Bio-oss, Geistlich) were inserted through the mini-round-like or mini-slot window until it filled the whole cavity, and implants were simultaneously placed (**Figure 1E**, **1F**). Resorbable collagen membranes (Bio-Gide; Geistlich) were used to cover all lateral windows. After proper reposition, full-thickness flaps were sutured with 5-0 Vicryl (Ethicon) horizontal mattress and interrupted sutures.

After surgery, amoxicillin (500 mg, thrice daily; Xinya Co., Shanghai, China) and metronidazole (400 mg, thrice daily; Xinyiwanxiang, Shanghai, China) were administered for 1 week, along with use of 0.12% chlorhexidine oral rinse (60 seconds, 5-6 times/day for 2 weeks), and the sutures were removed 10-14 days later. Six months after surgery, superstructures of implants were prepared and fixed on the alveolar bone.

Clinical and radiological follow-up

Patients were followed up once weekly in first postoperative month, and both intraoperative or postoperative complications were recorded. Intraoperative complications included excessive bleeding, perforation of membrane, and benign paroxysmal vertigo. Postoperative complications included swelling, ecchymosis, pain, loss of graft materials, and nasal bleeding.

CBCT was performed before surgery, immediately after surgery, and 6 months after surgery. Two investigators collected and reviewed the following radiographical parameters in a blind manner: residual bone height before surgery (Pre-RBH), immediate augmented bone height after surgery (Imm-ABH), and postoperative augmented bone height 6 months after surgery (6 M Post-ABH). Averages were calculated and expressed for both sets of measurements (**Table 1**).

Three-dimensional reconstructions of the CBCT scans were performed to view the three-dimensional images of the sinus grafts.

During implant placement and 6 months after surgery, implant stability quotient (ISQ) was determined using resonance frequency analysis (RFA) with the Osstell ISQ System (Osstell AB, Goteborg, Sweden) and SmartPeg (**Table 1**). In all cases, ISQ was calculated as the average of four measurements (facial, lingual, mesial, and distal) per implant.

Implant survival was determined by assessing the clinically detectable implant mobility, pain, subjective sensation, recurrent peri-implant infections, and continuous peri-implant radiolucency [12, 13].

Statistical analysis

Data are expressed as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) (F) and t test (t) were used for comparisons with statistical package for the social sciences (SPSS) (version 11.0; SPSS Inc., Chicago, IL). A value of $P<0.05$ was considered statistically significant.

Results

Clinical observations and assessments

A total of 20 patients (10 women and 10 men) aged 19-78 years (median: 46.1 years) participated in this study. In addition, bilateral maxillary sinus augmentation was performed in two patients, and thus a total of 22 sinus elevation procedures were conducted with placement of 46 implants. All the implants were repaired using superstructures with a cumulative survival rate (CSR) of 100%.

According to preoperative CBCT analysis and intraoperative observation, 10 sinuses were augmented via a mini-slot window and 10 by a mini-round-like window. No septa were noticed in the area of interest in any case. The average maximal height and width of the slot window were 4.1 ± 0.8 mm (range: 3-5.5 mm) and 10.7 ± 1.7 mm (range: 8-12.5 mm), respectively. The average maximal height and width of the mini-round-like window were 4.3 ± 0.6 mm (range 3.5-5 mm). The total volume of bone grafts used in each procedure was 2-5 cm^3. Clinical

Table 2. Clinical outcomes between mini-round-like and the mini-slot window approaches

Window Shape	Window Size		Radiographic Parameters					ISQ			
	Max H (mm)	Max W (mm)	RBH (mm)	Imm-ABH (mm)	6 M Post-ABH (mm)	F	P	Intra operation	6 M Post operation	F	p
Mini-slot	4.1 ± 0.8	10.7 ± 1.7	2.9 ± 0.5[a]	13.5 ± 0.8	13.1 ± 0.7	710.242	.000	61.9 ± 4.2[c]	76.1 ± 1.9	94.617	.000
Mini-round-like	4.3 ± 0.6	4.3 ± 0.6	3.2 ± 0.4[b]	13.6 ± 0.9	13.2 ± 0.9	704.268	.000	60.7 ± 3.4[d]	77.3 ± 2.6	182.119	.000
t			1.089	0.234	0.236			-0.765	1.231		
p			0.289	0.818	0.816			0.453	0.233		

Notes: Data were statistically analyzed using one-way ANOVA (F) and *t* test (*t*). *p* (probability) <0.05 represents statistically significant differences. No significant differences were observed in augmented bone height and ISQ between mini-round-like and the mini-slot window groups. a, b: vertical height of the sinus floor after surgery was significantly higher than that recorded before surgery in both mini-round-like and mini-slot window approaches ($P<0.05$). c, d: ISQ at 6 months after surgery was significantly higher than that recorded during surgery in both mini-round-like and mini-slot window groups ($P<0.05$). ANOVA: analysis of variance; ISQ: implant stability quotient; Max H: Maximum Height; Max W: Maximum Width; RBH: Remaining Bone Height. Imm-ABH: Immediately Postoperative Augmented Bone Height; 6 M Post-ABH: 6-Month Postoperative Augmented Bone Height.

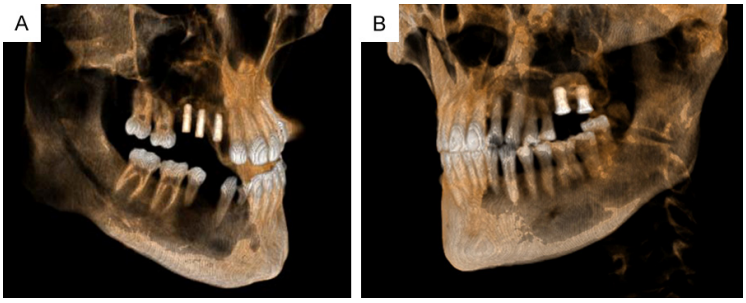

Figure 3. Three-dimensional images of sinus grafts at 6 months after surgery. Note: A: Case treated using the mini-round-like window approach; B: Case treated using the mini-slot window approach.

measurements are summarized in **Table 1**. The mean sizes for the two different windows are presented in **Table 2**.

Membrane perforation occurred in two procedures, and thus a resorbable collagen membrane was used to cover the perforation before graft placement in each case. Intraoperative or postoperative excessive bleeding was not observed in all these patients. Moreover, large intraosseous arteries were noted across the lateral sinus wall on CBCT slices during preoperative analysis and the slot ostectomy was done bypassing the artery. There was no benign paroxysmal vertigo, which occasionally occurs after severe osteotome preparation. Postoperative facial swelling was relatively milder than that observed after using the conventional lateral window approach. Postoperative complications such as ecchymosis, loss of graft materials, and nasal bleeding were not observed in these patients.

Radiographical assessment

Postoperative immediate radiography revealed that the augmented bone graft formed a dome with clear round margins under the elevated Schneiderian membrane. The apex of the implant was not exposed out of the dome or membrane (**Figure 1G**, **1H**). After 6-month follow-up, no residual particles of bone grafts were observed out of the windows, the reconstruction of the cortical plate at the osteotomy site was favorable, and no epithelial invaginations were noted on CBCT scans. **Figure 3** presents three-dimensional images of bone grafts after 6-month follow-up. **Table 1** enlists the mean values of all radiographical parameters. **Table 2** summarized the comparisons of these parameters between two different window approaches. There were no significant differences in the augmented bone height between two approaches.

Resonance frequency analysis (RFA)

RFA was performed for 46 implants. **Table 1** summarizes the mean ISQ. The ISQ at the time of implant placement was 55-68, with a mean of 61.2 ± 3.7. Six months after surgery, mean ISQ increased to 76.8 ± 2.4. **Table 2** presents the comparisons of ISQ between two different window approaches. No significant differences were observed in the ISQ between two approaches.

Discussion

The maxillary sinus floor elevation was first described by Tatum [7] in 1977, but the first study on this topic was first published in 1980 by Boyne and James [14]. Since then, it has been widely used in various preprosthetic sur-

gical procedures. Despite vast clinical researches and surgical experience, various novel techniques and new technology in past 30 years, no consensus has been achieved regarding which surgical technique would provide most favorable clinical outcomes [15]. However, one of the most important evolutional trends with lateral sinus floor elevation is that the surgical procedure should be simpler and minimally invasive, and the risk of complications be minimized. In this study, a modified sinus floor elevation via a mini-lateral window approach was introduced as a simpler and safer alternative for sinus augmentation, with simultaneous placement of dental implants, and the clinical and radiographical outcomes of this technique were further evaluated in 20 patients with severely resorbable posterior maxilla.

This modified technique is primarily based on the prerequisites that bone regeneration is more predictable when a defect is mainly surrounded by the host bone [16], and the cortical bone of the lateral sinus wall is greatly osteogenic [10]. Establishment of mini-windows on the lateral sinus wall enables greater cortical bone preservation as compared to conventional-sized window. Keeping this band of bone intact provides an immediate advantage as it helps to hold the biomaterials and expedites the repair of this window: this was confirmed by the absence of leakage of residual particles of bone grafts from the window, optimal reconstruction of the cortical plate at the osteotomy site, and absence of epithelial invaginations on CBCT scans after 6-month follow-up.

Moreover, the substantial preservation of lateral bone facilitates better healing by improving graft consolidation and maturation as well as formation of vital bone [9]. The vital bone around the surface of implants plays a critical role in osseointegration as well as in local response to functional loading and thus determines the success of implant placement [11]. The strength of the bone-implant anchorage is usually assessed by the stability of implants measured using RFA. RFA is clinically non-invasive and was introduced by Meredith *et al*. in 1996 [17]. the present study, the preprosthetic ISQ was significantly higher than the initial ISQ, which indicates that the strength of the bone-implant anchorage is enhanced along with more vital bone formation 6 months after surgery.

In this study, two types of mini-windows were established for modified sinus floor elevation: mini-round-like window and mini-slot window. The clinical indication to two different antrostomies is primarily determined by the number of implants required and the anatomy of the sinus. Typically, a mini-round-like window is used for single implant placement and a mini-slot window for multiple implant placement. Occasionally, mini-round-like window is used for the placement of multiple implants if the sinus has a wide lateral-to-medial anatomy, and no membrane adhesions are suspected.

Compared with the mini-round-like window approach, the mini-slot window approach can be used to gain greater surgical access and also to avoid blood vessels that are visible on CBCT scans to prevent bleeding. Results showed there were no significant differences in the clinical outcomes with respect to augmented bone height and ISQ. During the surgery, the obtained windows appeared slightly irregular since the surgical technique is free hand in nature; hence, maximal height and width of the windows were measured using a periodontal probe.

In this study, the augmented bone height was favorable in all cases, although the mini-window provided a small surgical field, which made the surgery more challenging. Notably, no additional operation time was required in this technique when compared with conventional technique. Based on radiography, the augmented bone graft formed a dome with clear round margins under the elevated Schneiderian membrane. The apex of the implant was not exposed out of the dome or membrane.

The modified technique via the mini-window minimizes the incision size and the periosteal flap elevation compared with the conventional technique, which reduces the incidence of postoperative complications such as swelling and pain. Sinus membrane perforation is one of the most common intraoperative complications associated with such grafting techniques [19]. According to previous studies, the prevalence of perforation, when a lateral window approach is used, is 3.6%-56% [20-23]; the incidence of membrane perforation when the modified technique is used was similar to that reported in previous studies. Thus, window preparation must be done carefully in order to prevent any membrane perforation.

Considering the limitations that the sample size was small and the follow-up period was relatively short in this study, our results indicate that simultaneous implant placement along with sinus augmentation via a mini-window achieves clinically favorable outcomes. This suggests that the technique may become a predictable treatment modality with a low prevalence of complications for severely resorbable posterior maxilla. Nevertheless, additional histomorphometric studies are needed to investigate the bone maturation, graft consolidation, and vital bone formation following maxillary sinus augmentation, and case-control studies are also required to better illustrate the superiority of this modified technique over the traditional technique.

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Disclosure of conflict of interest

None.

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