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Original Article

True vertical changes in patients with skeletal class III malocclusion after nonsurgical orthodontic treatment—a retrospective study comparing different vertical facial patterns

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KEYWORDS
Class III treatment;
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Vertical changes;
Vertical facial pattern

Abstract *Background/purpose:* Rotating mandible backward downward is one of the treatment options in non-surgical skeletal class III malocclusion. The purpose of this study was to compare the true vertical changes after camouflage orthodontic treatment of adult patients with skeletal class III malocclusion categorized by vertical facial type.
Materials and methods: This retrospective study included 27 adult patients (age >18 years) with skeletal class III malocclusion (ANB$<1°$) who underwent nonsurgical orthodontic treatment at Taipei Veterans General Hospital. The patients were divided into the low-angle (SN-MP$<28°$), high-angle (SN-MP$>36°$), and normal-angle ($28° \leq$ SN-MP $\leq 36°$) groups according to the original vertical facial pattern. Pretreatment (T1) and post-treatment (T2) lateral cephalograms were superimposed and treatment changes were evaluated.
Results: In all cases, proper overjet and occlusion were achieved after treatment, and the lower anterior facial height increased with the backward rotation of the mandibular plane. Increase in vertical dimension was the most obvious in the high-angle group, while it was the least obvious in the low-angle group. Extrusion of both the maxillary and mandibular incisors was observed in the high-angle group; however, intrusion of the maxillary and mandibular incisors and decreased overbite were observed in the low-angle group.
Conclusion: Camouflage orthodontic treatment of skeletal class III malocclusion improves the

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facial profile by increasing the vertical dimension and clockwise rotation of the mandible. According to our results, patients with a high mandibular plane angle showed better response to vertical dimension increment treatment mechanics than those with low and normal mandibular plane angles.
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Introduction

Treating skeletal class III malocclusions is one of the biggest challenges in orthodontics. Orthognathic surgery is often the best treatment option; however, many patients refuse this treatment because of the risks, morbidity, and costs involved. Alternatively, camouflage treatment can be planned for some of these skeletal problems. The three primary treatment strategies include maxillary dentition mesialization, mandibular dentition distalization, and vertical dimension increment.[1—6]

Increasing the vertical dimension with clockwise rotation of the mandible might be achieved by a posterior extrusive mechanism.[7,8] However, in routine clinical practice, even if a proper vertical dimension increment mechanism is applied, promising results might not be achieved in every patient. However, no research has been conducted on the efficacy of intentional vertical dimension increment in adult patients with skeletal class III malocclusion treated with nonsurgical orthodontic treatment.

Therefore, the purpose of this study was to compare the true vertical changes after camouflage treatment in adult patients with skeletal class III malocclusion. The patients were categorized into three groups according to the different vertical facial types.[9]

Materials and methods

This study was approved by the ethics committee at Taipei Veterans General Hospital (VGHTPE IRB No. 2020-03—006BC), and the need for informed consent was waived by the ethics committee because of the retrospective study design.

This retrospective study included 27 adult patients with skeletal class III malocclusion who underwent orthodontic treatment at our orthodontic Department. These patients were enrolled according to the following inclusion criteria: (1) skeletal class III discrepancy (ANB angle $\leq 1.0°$), (2) Angle's Class III molar relationship, (3) adult patients (age >18 years) who underwent orthodontic treatment only, and (4) patients with complete orthodontic treatment records. The exclusion criteria were as follows: (1) dentofacial anomalies, such as cleft lip and palate, and (2) an evident functional shift.

All study participants underwent fixed orthodontic therapy performed by a single orthodontist. To correct the class III dental relationship and prominent chin profile, the treatment aimed to increase the occlusal vertical dimension and achieve clockwise rotation of the mandible. Bite raisers on the incisors combined with short class III vertical elastics were the main treatment mechanics. Initially, a bite-raising material was added to the lower anterior teeth, and a posterior open bite was created. Full-time wearing of light short class III elastics (medium, 1/4-in, 3.5 oz; 3M) from the mandibular canine to the maxillary second premolar was prescribed to the patients to extrude the maxillary premolars and tip back the lower dentition. When occlusal contact was achieved in the posterior teeth, when and there was a sign of premolar extrusion and canine relation improvement, the bite raiser was adjusted at each appointment. The mean treatment period for all cases was 27.8 months.

Pretreatment (T1) and posttreatment (T2) lateral cephalograms were used for comparative analysis. All cephalograms were traced and identified by a single examiner (Fig. 1), and the measurements (Table 1) were calculated using a software (version 8, Image J). The representative data of skeletal vertical dimension were recorded as the lower anterior facial height (LAFH), mandibular plane angle (SN-MP), and Y-axis (NS-Gn). In addition, five dental vertical measurements were recorded (Table 1). Four skeletal and three dental anteroposterior measurements were also documented (Table 1).

Patients were divided into three groups according to their mandibular plane angle (SN-MP): (1) normal-angle group ($28° \leq$ SN-MP $\leq 36°$; n = 9), (2) high-angle group (SN-MP $> 36°$; n = 9), and (3) low-angle group (SN-MP $< 28°$; n = 9). General information of the patients was recorded (Table 2).

The differences between the three groups were identified through analysis of variance (ANOVA) followed by a post hoc (Bonferroni) test. The paired *t*-test was used to examine the changes before and after treatment (T1 vs. T2) in each group. All data analyses were performed using SPSS ver.17.0 (SPSS Inc. Chicago, IL, USA).

Results

The general information at pre-treatment stage on Table 2 showed that the extraction treatment plan was applied in most high-angle and normal-angle patient groups. However, the extraction treatment plan was applied in less than 50% of the cases in the low-angle group.

Pretreatment cephalometric data on Table 3 showed that the mean mandibular plane angle was significantly different between the three groups ($P < 0.001$). Regarding the severity of the anteroposterior skeletal relationship, the ANB angle data revealed that there was no significant difference between the groups at the pretreatment stage.

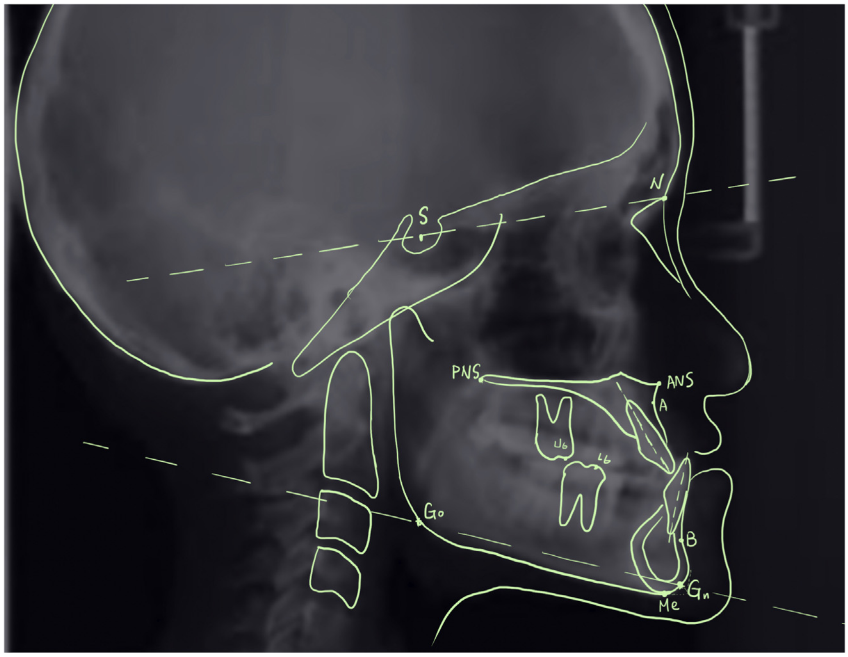

Figure 1 Cephalometric landmarks. Anatomic landmark: *N (nasion), S (sella), ANS (anterior nasal spine), PNS (posterior nasal spine), Go (gonion), Gn (gnathion), Me (skeletal menton), U6 (mesiobuccal cusp of the maxillary first molar), L6 (mesiobuccal cusp of the lower first molar).*

However, a retrusive point A was observed in the high-angle class III group (SNA, 79.4 ± 2.5° [high-angle group] vs. 84.4 ± 3.3° [low angle group], $P < 0.01$), and that a prominent point B was observed in the low-angle class III group (SNB, 80.1 ± 2.5° [high-angle group] vs. 86.9 ± 3.5° [low angle group], $P < 0.01$). As for the dental aspect, there was no significant difference in the linear vertical measurements at T1 stage, but the proclination of upper incisor

Table 1 Definitions of cephalometric measurements.

Variable	Definition
Skeletal (vertical)	
SN-MP (°)	The acute angle formed by the intersection of a line from S to N and a line from Go to Gn.
Y-axis (°)	The acute angle formed by the intersection of the line from S to N and the line from S to Gn.
LAFH (mm)	The linear distance from ANS to Me.
Skeletal (A-P)	
SNA (°)	The acute angle formed by the intersection of the line from S to N and the line from N to A.
SNB (°)	The acute angle formed by the intersection of the line from S to N and a line from N to B.
ANB (°)	The difference between the SNA and SNB angles
Pog-Nvert(mm)	The distance from Pog to the line N-Vert
Dental (vertical)	
U1-PP (mm)	The perpendicular distance from the lowest point on the maxillary incisor edge to the PP.
U6-PP (mm)	The perpendicular distance from the mesiobuccal cusp tip of the maxillary molar to the PP.
L1-MP (mm)	The perpendicular distance from the mesiobuccal cusp tip of the maxillary molar to the MP.
L6-MP (mm)	The linear distance from the mesiobuccal cusp tip of the mandibular molar to the MP.
OB (mm)	The amount of vertical incisor overlap, measured as a linear distance from the maxillary central incisor edge to the mandibular incisor edge.
Dnetal (A-P)	
U1-SN (°)	The angle formed by the intersection of a line from the maxillary incisor tip to the maxillary incisor root apex and a line from S to N.
L1-MP (°)	The angle formed by the intersection of a line from the mandibular incisor tip to the mandibular incisor root apex and a line from Go to Gn
OJ (mm)	The amount of horizontal incisor overlaps, measured from the labial surface of the mandibular incisors to the incisal edge of the maxillary incisors.

Abbreviations: Me (skeletal menton), Pog (skeletal pogonion), N-Vert (the line through point N and perpendicular to FH plane), PP (palatal plane: the line through ANS and PNS), MP (mandibular plane: the line through Go and Gn).

Table 2 General information of the patients at pretreatment stage (T1).

	High angle	Normal angle	Low angle
Sample size	9	9	9
Sex (M/F)	1/8	2/7	4/5
Age (y/o)	22.7	22.5	26
Treatment duration (months)	30.1	27.4	28.0
Extraction/non-extraction	9/0	8/1	4/5
SN-MP (°)	40.2	30.2	23.6

was obvious in the low-angle class III group (U1-SN, 105 ± 4.6° [high-angle group] vs. 114 ± 5.5° [low-angle group], $P = 0.04$).

Cephalometric variables at pretreatment (T1) and posttreatment (T2) stages were shown on Table 4. After treatment, all class III cases achieved an improvement in overjet and increased lower anterior facial height, mandibular plane angle (SN-MP), and ANB angle, all of which met our initial treatment goal.

Regarding the dental aspect, the maxillary incisors and molars (U1-PP and U6-PP) and the mandibular molars (L6-MP) extruded significantly in the high-angle group after treatment. However, neither the upper nor the lower dentition showed obvious dental extrusion in the low-angle group after nonsurgical treatment.

Table 5 demonstrated the changes in cephalometric variables from T1 to T2 stage. ANOVA followed by Bonferroni post hoc test showed that the LAFH increments were significantly different between the high-angle (2.21 ± 1.27 mm) and low-angle groups (0.59 ± 0.91 mm); $P = 0.013$). Regarding vertical dental changes, significant difference was observed in maxillary incisor extrusion between the high-angle (1.56 ± 1.46 mm) and low-angle groups (−0.75 ± 1.61 mm; $P = 0.008$).

Discussion

Class III skeletal malocclusion can be treated with nonsurgical orthodontic therapy according to patients' requirement, when most of the dental and skeletal criteria fit the favorable factors of nonsurgical treatment.[1,3,5] In their study, Liou et al. mentioned the efficacy of vertical increment mechanics in treating class III malocclusion in late teenagers.[5] Tseng et al. concluded that hypodivergent facial pattern (gonial angle <120.8°) was one of the favorable factors for nonsurgical orthodontic treatment.[10] Camouflage orthodontic treatment in patients with class III malocclusion involves clockwise rotation of the mandibular plane by extrusion of the dentition, which helps in reducing anteroposterior discrepancy and maintaining the anteroposterior tooth movement within the biological envelope. In this study, all included patients were adult non-growing patients. Our study results showed that all three groups had achieved positive overjet after orthodontic treatment. Mandibular plane increments of 0.92°, 0.92°, and 0.51° were noted in the high-angle, normal-angle, and low-angle groups, respectively, with statistical significance between T1 and T2. However, there was no obvious difference between the three groups ($P = 0.382$) (Table 5). However, in the linear measurement, a significant difference was observed in the LAFH increment between the high-and low-angle groups after the post hoc test ($P = 0.13$) (Table 5). The

Table 3 Cephalometric variables of the patients at pretreatment stage (T1).

Variable	High angle (n = 9)	Normal angle (n = 9)	Low angle (n = 9)	P value	Bonferroni (Post hoc)
Skeletal (Vertical)					
SN-MP (°)	40.2 ± 3.6	30.2 ± 1.4	23.6 ± 3.1	**<.001***	**H > L** H>N N>L
Y-axis (°)	71.7 ± 2.8	65.6 ± 2.1	63.6 ± 2.5	**<.001***	**H > L** H>N
LAFH (mm)	77.2 ± 2.6	73.3 ± 4.9	70.2 ± 6.0	**.015***	**H>L**
Skeletal (A-P)					
SNA (°)	79.4 ± 2.5	83.9 ± 1.6	84.4 ± 3.3	**<.001***	**H<L** H<N
SNB (°)	80.1 ± 2.5	85.7 ± 1.9	86.9 ± 3.5	**<.001***	**H<L** H<N
ANB (°)	−0.7 ± 1.3	−1.8 ± 1.8	−2.6 ± 1.5	0.057	
Pog-Nvert (mm)	−2.3 ± 5.1	−0.5 ± 2.1	−0.7 ± 2.6	**.018***	**H<L**
Dental (Vertical)					
U1-PP (mm)	31.8 ± 2.0	30.4 ± 2.1	28.5 ± 3.9	0.052	
U6-PP (mm)	27.0 ± 1.3	26.5 ± 2.7	26.1 ± 2.8	0.758	
L1-MP (mm)	45.2 ± 3.4	44.7 ± 4.6	45.8 ± 4.0	0.840	
L6-MP (mm)	36.0 ± 3.0	35.8 ± 4.6	37.3 ± 3.5	0.657	
OB (mm)	0.6 ± 1.6	1.3 ± 2.6	3.3 ± 2.9	0.069	
Dental (A-P)					
U1-SN (°)	105.1 ± 4.6	111.3 ± 5.3	114.0 ± 5.5	0.004*	**H<L**
L1-MP (°)	83.5 ± 8.9	87.1 ± 5.4	91.8 ± 6.3	0.061	
OJ (mm)	−0.8 ± 2.5	0.2 ± 2.5	−1.8 ± 2.2	0.213	

Significance was set at $^*P < 0.05$.
Intergroup comparison with ANOVA and Bonferroni post hoc test.
Values are presented as mean ± standard deviation (SD).
Abbreviations: H (High angle); N (Normal angle); L(Low angle); ANOVA(analysis of variance).

Table 4 Cephalometric variables of the patients at pretreatment (T1) and posttreatment (T2) stages.

Variable	High angle (n = 9)			Normal angle (n = 9)			Low angle (n = 9)		
	T1	*T2*	*P value*	*T1*	*T2*	*P value*	*T1*	*T2*	*P value*
Skeletal (Vertical)									
SN-MP (°)	40.3 ± 3.5	41.2 ± 3.5	0.014*	30.2 ± 1.4	31.1 ± 1.8	0.007*	23.6 ± 3.1	24.2 ± 3.0	0.005*
Y-axis (°)	71.8 ± 2.9	72.8 ± 2.9	0.006*	65.6 ± 2.1	66.2 ± 1.7	0.055	63.6 ± 2.5	64.1 ± 2.7	0.020*
LAFH (mm)	76.5 ± 2.5	78.7 ± 2.3	0.001*	73.4 ± 4.7	74.8 ± 4.2	0.003*	70.2 ± 6.0	70.8 ± 5.9	0.091
Skeletal (A-P)									
SNA (°)	79.3 ± 2.5	79.0 ± 2.5	0.357	84.0 ± 1.5	83.6 ± 1.8	0.052	84.4 ± 3.3	84.0 ± 3.4	0.041*
SNB (°)	80.0 ± 2.7	78.7 ± 2.4	0.004*	85.8 ± 1.8	84.7 ± 1.7	0.005*	86.9 ± 3.5	86.0 ± 4.0	0.002*
ANB (°)	−0.7 ± 1.4	0.3 ± 0.9	0.028*	−1.8 ± 1.8	−1.1 ± 1.5	0.020*	−2.6 ± 1.5	−2.0 ± 1.5	0.016*
Pog-Nvert (mm)	−2.1 ± 5.4	−4.1 ± 5.3	0.012*	3.2 ± 4.5	2.6 ± 4.2	0.350	4.3 ± 4.9	2.2 ± 3.4	0.063
Dental (Vertical)									
U1-PP (mm)	31.5 ± 1.7	33.0 ± 1.4	0.014*	30.5 ± 2.1	31.2 ± 1.7	0.105	28.4 ± 3.9	27.7 ± 2.7	0.200
U6-PP (mm)	26.7 ± 0.0	28.1 ± 0.5	0.007*	26.5 ± 2.7	27.7 ± 2.5	0.010*	26.1 ± 2.8	26.4 ± 2.5	0.234
L1-MP (mm)	45.0 ± 3.1	45.4 ± 2.8	0.560	44.8 ± 4.6	43.5 ± 3.6	0.086	45.8 ± 4.0	44.7 ± 3.6	0.079
L6-MP (mm)	35.7 ± 2.7	37.1 ± 2.3	0.030*	35.8 ± 4.5	36.3 ± 3.4	0.458	37.3 ± 3.5	37.2 ± 3.6	0.831
OB (mm)	0.6 ± 1.6	1.4 ± 0.6	0.129	1.3 ± 2.6	1.2 ± 0.7	0.843	3.3 ± 2.9	1.8 ± 0.9	0.167
Dental (A-P)									
U1-SN (°)	105.1 ± 4.4	105.5 ± 4.2	0.807	111.2 ± 5.4	110.6 ± 4.0	0.806	114.0 ± 5.5	117.3 ± 5.9	0.146
L1-MP (°)	83.1 ± 7.9	79.4 ± 4.7	0.210	87.1 ± 5.	80.1 ± 9.2	0.025*	91.8 ± 6.3	85.8 ± 10.5	0.030*
OJ (mm)	−0.7 ± 2.4	3.0 ± 0.8	0.002*	0.2 ± 2.5	2.9 ± 0.7	0.014*	−1.8 ± 2.2	3.0 ± 0.9	<0.001*[1–15]

Statistical significance was set at *P < 0.05.
Paired *t*-test for T1 vs T2 for intra-group comparison.
Values are presented as mean ± standard deviation (SD).

changes in SN-MP angle were defined by four points, which might increase the percentage of measurement errors. However, LAFH was a more straightforward measurement, representing true linear changes between two points. Increment in the LAFH was approximately 0.59 mm in the low-angle group and 2.21 mm in the high-angle group. Thus, it is difficult to increase the LAFH beyond a certain limit in patients with class III malocclusion and low

Table 5 Changes in cephalometric variables of the patients from T1 to T2.

Variable	High angle (n = 9)	Normal angle (n = 9)	Low angle (n = 9)	P value	Bonferroni Post hoc
	T2-T1	T2-T1	T2-T1		
Skeletal (vert)					
SN-MP (°)	0.92 ± 0.89	0.92 ± 0.75	0.51 ± 0.4	0.382	
Y-axis (°)	1.03 ± 0.79	0.56 ± 0.74	0.50 ± 0.52	0.226	
LAFH (mm)	2.21 ± 1.27	1.35 ± 0.98	0.59 ± 0.91	**.013***	H>L
Skeletal (AP)					
SNA (°)	−0.22 ± 0.72	−0.34 ± 0.44	−0.39 ± 0.48	0.804	
SNB (°)	−1.24 ± 0.98	−1.06 ± 0.82	−0.91 ± 0.58	0.678	
ANB (°)	1.03 ± 1.17	0.51 ± 0.50	0.72 ± 0.75	0.438	
Pog-Nvert (mm)	−2.06 ± 1.84	−1.04 ± 1.05	−0.60 ± 1.81	0.165	
Dental (vert)					
U1-PP (mm)	1.56 ± 1.46	0.73 ± 1.21	−0.75 ± 1.61	**.008***	H>L
U6-PP (mm)	1.31 ± 1.10	1.15 ± 1.04	0.30 ± 0.70	0.077	
L1-MP (mm)	0.44 ± 2.14	−1.21 ± 1.86	−1.17 ± 1.75	0.136	
L6-MP (mm)	1.43 ± 1.65	0.42 ± 1.60	−0.06 ± 0.77	0.090	
OB (mm)	0.89 ± 1.58	−0.17 ± 2.45	−1.50 ± 2.96	0.128	
Dental (A-P)					
U1-SN (°)	0.39 ± 5.15	−0.54 ± 6.41	3.34 ± 6.23	0.368	
L1-MP (°)	−3.74 ± 8.22	−5.95 ± 6.76	−6.96 ± 7.61	0.658	
OJ (mm)	3.72 ± 2.48	2.67 ± 2.54	4.83 ± 2.35	0.195	

Statistical significance was set at *P < 0.05.
Inter-group comparison with ANOVA and Bonferroni post hoc test.
Values are presented as mean ± standard deviation (SD).
Abbreviations: *H (High angle); N(Normal angle); L (Low angle).*

mandibular plane angle. This may be related to the bite force variation in different facial patterns.[11]

Therefore, camouflage treatment goals in such class III cases should rely on actual anteroposterior dental movement with proper mechanical design and biological limit considerations. From an anatomic point of view, patients with low mandibular angle mostly have shorter lower dental alveolar height and thicker symphysis comparing to patient with high mandibular plane angle.[12] Distalization of the lower dentition using miniscrew anchorage or the multiloop edgewise arch wire technique might be an alternative way to achieve proper overjet.[1,2,4,6] The success rate of miniscrew as anchorage to achieve total arch distalization had been proved to be high.[13—15]

On comparing the vertical dental changes after treatment, we observed that only the maxillary incisor position showed significant changes in the high-angle group (Table 5). Extrusion of the maxillary incisor in the high-angle group might have resulted from the successful increment in the LAFH and incisor dumping after extraction space closure. However, the low angle group patient had deep bite (3.3 mm at T1) at beginning. To solve the deep overbite, if increment of LAFH could not be achieved, intrusion of incisors had to be done. Therefore, maxillary incisor intrusion was noticed at low angle group. Obvious dental compensation was noted in the low-angle group, and increased proclination of the maxillary incisor (3.34°) and retroclination of the mandibular incisor (−6.96°) were clinically significant compared with the values in the high-angle group. Although the final positive overjet could be achieved in the low-angle group, improvement in facial profile was not achieved (Pog-Nvert: −0.6 mm). Contrarily, dental compensation in the high-angle group was less (U1-SN: 0.39°, L1-MP: −3.74°), the profile improvement was better (Pog-Nvert: −2.06 mm) (Table 5). Although there was no statistical significance, the treatment results trend might suggest that profile improvement and upper incisor inclination correction by vertical increment in adult patients with class III malocclusion and low mandibular plane angle might not be a predictable treatment goal.

Optional genioplasty after orthodontic camouflage treatment in such cases might improve the prominent chin and short lower face. However, proclination of the upper incisors cannot be resolved without orthognathic surgery.

The vertical increment and facial profile improvement in adult patients with class III malocclusion was achievable; however, the LAFH increment was significantly lower in patients with a low mandibular plane angle than patient with a high mandibular plane angle. Further research involving more cases and long-term follow-up data is needed to verify the improvement and stability of this treatment strategy for adult class III patients.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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