International Journal of Dental Research and Allied Sciences
2023, Volume 3, Issue 2, Page No: 104-111

Available online at: www.tsdp.net

ISSN: 3062-3502

Original Article

Cephalometric Assessment of Lower Incisor—Pg in Relation to Skeletal Patterns

Hana Watanabe[1]*, Daiki Ito[1], Mei Nakamura[1]

[1]Department of Orthodontics and Craniofacial Developmental Biology, Graduate School of Biomedical and Health Sciences, Hiroshima University, Hiroshima 734-8553, Japan.
[2]Department of Medical Systems Engineering, Graduate School of Biomedical and Health Sciences, Hiroshima University, Hiroshima 734-8553, Japan.

***E-mail** ✉ hwatanabe88@gmail.com

Received: 26 August 2023; **Revised:** 28 November 2023; **Accepted:** 02 December 2023

ABSTRACT

This retrospective investigation sought to propose a new linear indicator, Lower Incisor—Pg, and to examine how this measurement behaves across various vertical and sagittal skeletal configurations. A dataset of 1256 lateral cephalometric radiographs was retrospectively analyzed. Subjects were categorized according to SN^Go-Gn, ANPg^, and IMPA parameters. Differences in Lower Incisor—Pg among groups were tested through ANOVA and post hoc comparisons, while Pearson correlation was used to explore inter-variable associations. The mesofacial pattern appeared most frequently (61.0%), followed by dolichofacial (30.0%) and brachyfacial (8.6%) morphologies. For the sagittal relationships, Class I predominated (70.9%) compared with Class II (19.3%) and Class III (9.8%). The average Lower Incisor—Pg value was 3.2 ± 4.0 mm. Regression analysis yielded β coefficients of 0.45 for ANPg^ and 0.36 for SNGoGn^. The Lower Incisor—Pg can serve as a direct cephalometric index for assessing the anteroposterior position of the lower incisor. Each 1° increment in ANPg^ and SNGoGn^ corresponded to 0.45 mm and 0.36 mm increases, respectively, in Lower Incisor—Pg.

Keywords: Lower incisor assessment, Cephalometric reference, Orthodontic metrics, Diagnostic evaluation, Craniofacial morphology, Vertical pattern

How to Cite This Article: Watanabe H, Ito D, Nakamura M. Cephalometric Assessment of Lower Incisor—Pg in Relation to Skeletal Patterns. Int J Dent Res Allied Sci. 2023;3(2):104-11. https://doi.org/10.51847/3clsWTm1HY

Introduction

Achieving both aesthetic balance and functional integrity has long been central to orthodontic analysis and treatment design [1]. While the perception of beauty is inherently subjective [2], numerous studies have identified objective craniofacial parameters that align with what is considered visually pleasing, making them valuable adjuncts to clinical judgment in therapy planning [3]. Among the dental elements, the lower incisors are especially influential in maintaining facial harmony and masticatory function, with their sagittal orientation closely tied to facial profile and dynamics [1]. Adjustments in the anteroposterior position of these teeth are directly associated with lip posture and thickness—specifically, retraction of the lower incisors tends to result in posterior lip displacement and reduced lip volume.

The spatial position of the lower incisors is affected by both vertical and sagittal skeletal morphology [4]. From a vertical standpoint, dolichofacial individuals often display retroclined incisors, whereas brachyfacial patterns tend toward proclination [5]. In contrast, when sagittal disharmony exists, the lower incisors often compensate for skeletal imbalances through inclination changes. From a periodontal viewpoint, however, excessive proclination can lead to gingival recession, bony dehiscence, or fenestrations, particularly in patients with thin gingival tissue [6–8].

The placement of the lower incisors is also influenced by arch space management, especially when correcting anterior crowding [9]. Among space-gaining strategies, controlled tooth movement is the most conservative approach, given that distalization and expansion are restricted by mandibular structural boundaries [10]. Since the maxillary arch does not face the same anatomical constraints, the upper incisor position can be subsequently modified to harmonize with that of the lower incisors [11].

Recognizing the diagnostic significance of lower incisor positioning in orthodontic therapy [12], numerous cephalometric indicators have been proposed to define its ideal anteroposterior location [5]. Margolis introduced the Incisor–Mandibular Plane Angle (IMPA)—the angle formed between the mandibular plane and the long axis of the incisor [13]. Later, Tweed noted that this angle was highly dependent on mandibular shape, and therefore proposed a diagnostic triangle involving FMIA, FMA, and IMPA, allowing for the inclusion of vertical skeletal influences when determining prognosis [14, 15].

Subsequently, Ricketts linked the mandibular incisor to cranial reference points, developing an angular cephalometric index—the angle between the lower incisor axis and the Frankfurt horizontal plane (B1–FH) [16]. As the Frankfurt plane runs parallel to the horizontal reference line, the B1–FH value depends solely on incisor inclination rather than cranial tilt.

Despite their wide use, traditional angular measures such as IMPA exhibit limitations when applied to subjects with pronounced verticality or severe sagittal discrepancies [17]. Linear references like A–Pog (Ricketts) and NB (Steiner) [1] are likewise affected by variations in maxillary and cranial alignment. To address these shortcomings, the present study aimed to (1) introduce a new linear cephalometric metric, the Lower Incisor—Pg, designed to represent the relationship between the anterior dentition and skeletal framework, and (2) evaluate its behavior across vertical and sagittal skeletal dimensions.

Accordingly, a preliminary cephalometric assessment of sagittal and vertical skeletal characteristics, as well as lower incisor positioning, was performed in a population sample stratified by age and sex.

Materials and Methods

This retrospective investigation utilized original lateral cephalometric radiographs from 1836 individuals who were examined at the Section of Orthodontics, University of Naples Federico II, Naples, Italy. All images were anonymized, retaining only information about each subject's age and sex.

Inclusion criteria

- *Subject age:* only radiographs of patients older than 8 years were included to ensure full eruption of the central incisors (average eruption age: 6 ± 12 months) [18];
- *Radiograph quality:* only high-resolution lateral cephalometric radiographs were selected.

Exclusion criteria

- *Age*: radiographs of patients younger than 8 years;
- *Prior interventions:* images from individuals with dental implants, prosthetic restorations, or previous orthodontic therapy;
- *Image quality:* cephalograms with motion artifacts, patient misalignment, or unclear visualization of the central incisors were excluded.

If two cephalometric records existed for the same individual—one taken in habitual occlusion and the other in centric occlusion—only the centric occlusion image was analyzed.

Sample grouping

Participants were separated into two age-based cohorts:

- *Growing group:* individuals aged 8–18 years;
- *End-growth group:* individuals older than 18 years.

Cephalometric evaluation

A single calibrated examiner (M.G.) performed all measurements independently using Delta-Dent software version 2.0 (Delta-Dent CE—Outside Format, Pandino, CR, Italy). Calibration was standardized, and in cases of double-point projection, the midpoint was recorded.

The reference points and angular parameters used in the cephalometric assessment are summarized in **Table 1** and illustrated in **Figure 1**.

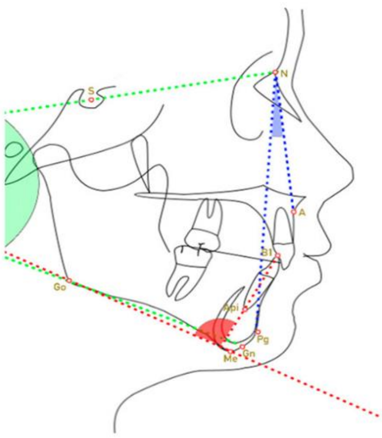


Figure 1. Parameters included in the cephalometric analysis. The angle marked by the blue lines is the ANPg^. The angle marked by the green lines is SN^Go-Gn. The angle marked by the red lines is IMPA.

- The blue-marked angle represents ANPg^.
- The green-marked angle indicates SN^Go-Gn.
- The red-marked angle denotes IMPA.

Table 1. Cephalometric points and angular measurements

Cephalometric Reference	Anatomical Description
Nasion (Na)	The frontmost junction of the nasal and frontal bones
Menton (Me)	The lowest central point on the mandibular symphysis outline
Sella turcica (S)	The central landmark within the sella turcica structure
Orbitalis (Or)	The deepest point at the base of the orbital cavity
Porion (Po)	The superior posterior edge of the external ear canal
Pogonion (Pg)	The most prominent anterior point on the chin's bony contour
Subspinal point (A)	The innermost point in the maxillary anterior concavity, situated between the anterior nasal spine and alveolar ridge
Gnathion (Gn)	The midpoint located between pogonion and menton on the mandible
Lower Incisor Incisal Edge	The tip of the cutting edge of the lower incisor
Lower Incisor Root Apex	The terminal point of the lower incisor's root

The vertical and sagittal skeletal configurations were analyzed using:

- SN^Go-Gn: the angle formed by the N–S plane and the Go–Gn plane;
- ANPg^: the angle formed among Point A, Nasion, and Pogonion.

The IMPA (the angle between the axis of the lower incisor and the mandibular plane Go–Me) quantified the lower incisor inclination.
Group classifications based on measurements
According to the cephalometric data, the sample was divided as follows:

- Vertical skeletal type:
    - Mesofacial: SN^Go-Gn between 27°–37°
    - Brachyfacial: SN^Go-Gn < 27°
    - Dolichofacial: SN^Go-Gn > 37° [19].

- Sagittal skeletal type:
    - Class I: ANPg^ between −1° and 5°
    - Class II: ANPg^ > 5°
    - Class III: ANPg^ < −1° [19].

- Lower incisor inclination:
    - Normoclined: IMPA 90° ± 5°
    - Proclined: IMPA > 95°
    - Retroclined: IMPA < 85°.

For all individuals, the linear distance from the line perpendicular to the Frankfurt plane passing through the incisal edge of the lower incisor to the Pogonion (Lower Incisor–Pg) was measured **(Figure 2)**.

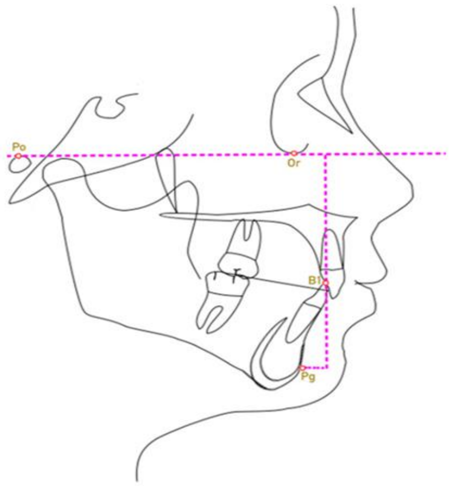


Figure 2. Lower Incisor—Pg parameter.

Statistical procedures
For each dataset, means and standard deviations were computed. The Shapiro–Wilk test was applied to verify normality.
Differences in means between the growing vs. end-growth groups and between males and females were examined using the z-test.
=ANOVA followed by post hoc comparisons evaluated discrepancies in Lower Incisor–Pg across:

- Vertical facial types (brachyfacial, mesofacial, dolichofacial),
- Sagittal skeletal classes (Class I, II, III), and
- Incisor inclination categories (normoclined, proclined, retroclined).

Pearson's correlation assessed the relationship between Lower Incisor–Pg and ANPg^, SN^Go-Gn, and IMPA.
Finally, linear regression determined how Lower Incisor–Pg varied with those parameters.
All analyses were conducted using SPSS software (version 28.0; IBM SPSS, Armonk, NY, USA), setting statistical significance at $p < 0.05$.

Results and Discussion

From the total collection of records, 1256 individuals met the inclusion criteria — 684 women and 572 men — aged between 8 and 57 years.

The corresponding cephalometric outcomes are summarized in **Table 2**.

Table 2. Cephalometric indicators of skeletal and dental characteristics by sex.

Cephalometric Parameters	N (%)	Mean ± SD (mm) All Subjects	Mean ± SD (mm) Female Subjects	Mean ± SD (mm) Male Subjects	p-Value *
SN^Go-Gn		35.2 ± 5.6	33.3 ± 5.5		<0.001
Mesofacial	766 (61.0%)	32.7 ± 3.0			
Dolichofacial	381 (30.3%)	40.2 ± 4.1			
Brachyfacial	109 (8.7%)	25.1 ± 4.0			
ANPg^		2.7 ± 2.6	2.5 ± 2.9		0.193
Skeletal Class I	890 (70.9%)	2.3 ± 1.8			
Skeletal Class II	243 (19.3%)	5.8 ± 1.9			
Skeletal Class III	123 (9.8%)	−1.9 ± 2.4			
IMPA		95.5 ± 7.4	96.1 ± 7.9		0.147
Normoclined	484 (38.5%)	91.6° ± 4.3			
Proclined	680 (54.1%)	100.6° ± 5.3			
Retroclined	92 (7.3%)	82.4° ± 6.1			

* Independent z-test, significance threshold p < 0.05.

All examined parameters—ANPg^, SN^Go-Gn, and IMPA—showed normal distribution across both genders. Only the SN^Go-Gn angle exhibited a statistically significant difference between males and females ($p < 0.001$).

In the growth-phase group (n = 1009) and the post-growth group (n = 247), the variables SN^Go-Gn, ANPg^, and IMPA were also normally distributed. Differences in ANPg^ ($p < 0.001$) and IMPA ($p = 0.011$) were significant between the two age categories. The detailed cephalometric data for these groups appear in **Table 3**.

Table 3. Cephalometric characteristics of the analyzed sample grouped by age.

Cephalometric Parameters	Mean ± SD (mm) Growing Group	Mean ± SD (mm) End-Growth Group	p-Value *
SN^Go-Gn	34.2 ± 5.3	33.9 ± 6.9	0.938
ANPg^	2.8 ± 2.7	1.7 ± 2.9	<0.001
IMPA	96.1 ± 7.5	94.6 ± 8.0	0.011

* Independent z-test, significance threshold p < 0.05.

The mean Lower Incisor–Pg measurement equaled 3.2 ± 4.0 mm. This variable followed a normal distribution pattern and did not differ significantly by sex ($p = 0.213$). However, a significant distinction emerged between the age cohorts ($p < 0.001$).

Comparisons among subjects classified according to vertical and sagittal skeletal patterns and IMPA categories revealed statistically significant variations in Lower Incisor–Pg, as presented in **Table 4**.

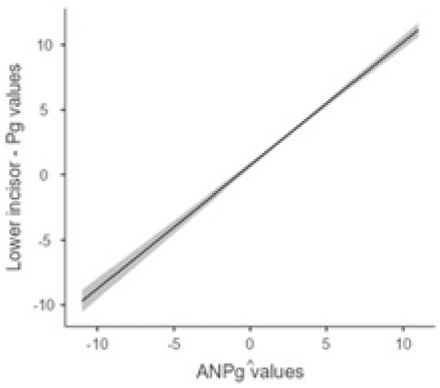
Table 4. Mean Lower Incisor–Pg distances based on skeletal vertical/sagittal pattern and incisor inclination.

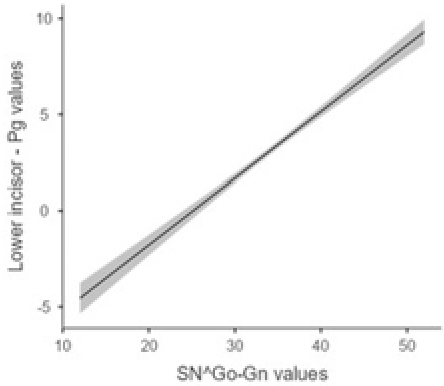
Subject Category	Lower Incisor—Pg Mean ± SD (mm)	p-Value *
Mesofacial	2.7 ± 3.6	<0.001
Dolichofacial	5.2 ± 3.9	
Brachyfacial	−0.5 ± 3.6	
Skeletal Class I	2.9 ± 3.5	<0.001
Skeletal Class II	6.3 ± 3.7	
Skeletal Class III	−0.9 ± 3.9	
Normoclined incisor	2.4 ± 3.9	<0.001
Proclined incisor	4.2 ± 3.8	
Retroclined incisor	−0.3 ± 3.7	

* ANOVA, significance set at p < 0.05.

Correlation analysis demonstrated a strong positive association between Lower Incisor–Pg and both ANPg^ and SNGoGn^ (Pearson's $r = 0.792$, $p < 0.001$). In the linear regression model, the β values for ANPg^ and SNGoGn^ were 0.45 and 0.36, respectively **(Figure 3)**.

No relevant linear association was observed between Lower Incisor–Pg and age, either for the full cohort (Pearson's $r = 0.10$, $p < 0.001$) or within the growing subgroup alone (Pearson's $r = 0.086$, $p = 0.006$).





a) b)

Figure 3. Scatterplots representing regression trends between Lower Incisor–Pg and (a) sagittal and (b) vertical skeletal variables.

Within the analyzed population, the mesofacial growth pattern was predominant (61.0%), followed by dolichofacial (30.0%) and brachyfacial (8.6%) morphologies.

Regarding sagittal skeletal configuration, Class I represented the majority (70.9%), while Class II and Class III accounted for 19.3% and 9.8%, respectively.

Since craniofacial proportions vary geographically, comparisons are most accurate when data are drawn from populations of the same regional or ethnic background [20]. Despite variability reported in global datasets, the present findings closely mirror those observed in D'Antò *et al*. [19], whose sample was similarly composed of individuals from Southern Italy. The distribution of skeletal Classes I and II observed here parallels the corresponding dental class frequencies described in prior epidemiological surveys [21]. However, the lower prevalence of skeletal Class III does not fully reflect the dental classification reported elsewhere [22], probably due to compensatory tooth movements that can obscure mild skeletal discrepancies and slightly alter points A and B on cephalometric tracings [21].

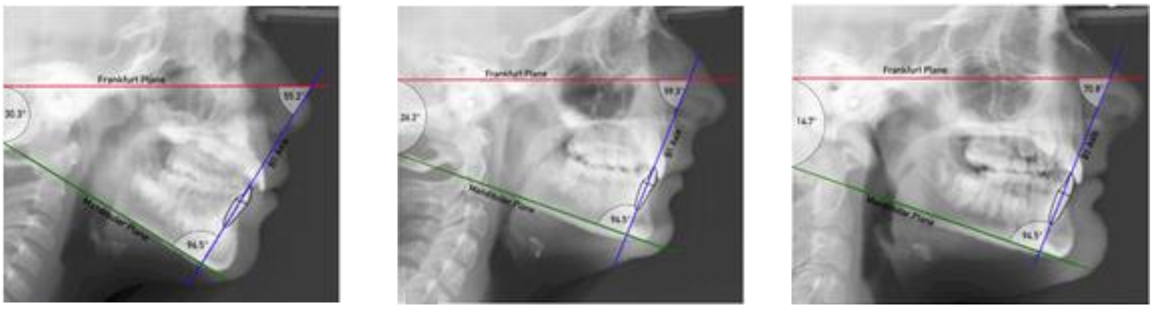
Between sexes, a notable difference was seen in SN^Go-Gn, consistent with evidence of forward mandibular rotation in males—reducing the mandibular plane angle—and posterior rotation in females, which increases it [23].

When growth status was considered, ANPg^ values were significantly lower among adults, likely because mandibular sagittal growth extends beyond that of the maxilla [24]. In alignment with this, Class III skeletal patterns occurred in 7.8% of the growing group (n = 79/1009) and 17.8% of the adult group (n = 44/247).

The mean IMPA value significantly varied between growing and post-growth individuals, showing a slight reduction in adults. Physiologically, the normal mandibular rotation that occurs during growth modifies the eruption trajectory of the lower incisors, generally causing them to upright and move lingually [25].

The Lower Incisor–Pg parameter represents the linear distance between a line perpendicular to the Frankfurt horizontal (FH) passing through the incisal edge of the lower incisor and the Pogonion (Pg). Because this metric depends solely on the incisal margin and the Pogonion, it remains independent of mandibular plane inclination (Go–Me), thereby overcoming the principal limitation associated with IMPA, which is strongly influenced by mandibular plane steepness.

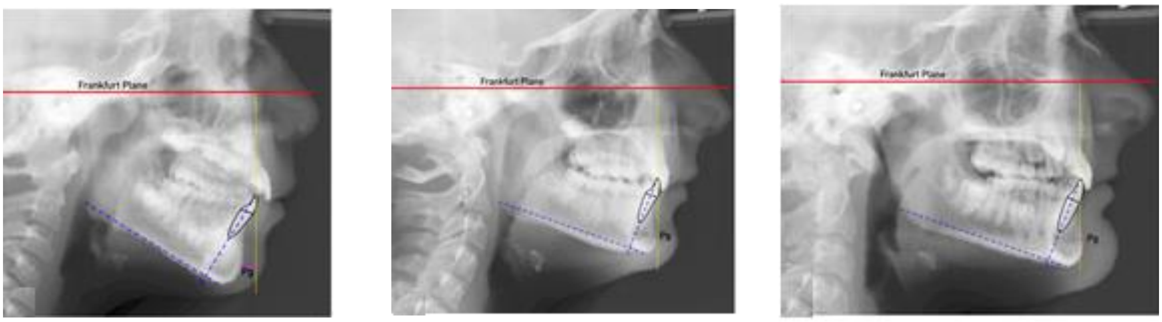
Figure 4 presents three lateral cephalograms obtained from this study. When comparing the B1–FH angle, the incisor in radiograph A appears more proclined than in B and C. Nonetheless, all three display identical IMPA values, due to differing mandibular plane angles. Thus, the IMPA alone cannot accurately represent the true spatial position of the lower incisor unless it is considered alongside the Go–Me–FH angle (mandibular plane angle) [26].



a) b) c)

Figure 4. Following Tweed's definition, the triangle formed by the Frankfurt plane (red line), the mandibular plane Go–Me (green line), and the B1 incisor axis (blue line) delineates three critical angular relationships: IMPA (mandibular plane–B1), mandibular plane angle (Go–Me–FH), and B1–FH. Though all subjects share an identical IMPA, their mandibular plane angles differ: subject a is hyperdivergent, subject b is normodivergent, and subject c is hypodivergent. As the mandibular plane angle decreases, the B1–FH angle proportionally increases.

Figure 5 depicts the same radiographs from **Figure 4**. In contrast to the unchanged IMPA, the Lower Incisor–Pg measurement varies among the three individuals, reflecting differences in B1–FH inclination and confirming that mandibular plane angle has no effect on this specific parameter.



a) b) c)

Figure 5. The change in B1–FH observed in Figure 4 corresponds to the variation in Lower Incisor–Pg (purple line), measured between the Pogonion (Pg) and the line perpendicular to FH (red line) passing through the incisal edge of the lower incisor (yellow line). Subject a demonstrates an increased value, subject b a normal one, and subject c a reduced measurement.

Within the analyzed cohort, the average Lower Incisor–Pg was 3.2 ± 4.0 mm. Similar to the IMPA, this parameter did not differ statistically between sexes, whereas significant variation was evident between the growing and post-growth categories.

Although Lower Incisor–Pg remains unaffected by mandibular plane inclination, statistically significant distinctions appeared among subgroups divided by vertical and sagittal skeletal relationships. This occurs because the Pogonion position, which defines the Lower Incisor–Pg, is influenced by the vertical and sagittal orientation of the mandible.

Still, such alterations in Lower Incisor–Pg related to mandibular displacement follow a predictable pattern. Linear regression analysis revealed that:

- For each 1° increase in ANPg^, Lower Incisor–Pg rises by 0.45 mm, and
- For each 1° increase in SNGoGn^, it increases by 0.36 mm.

Comparable trends are reported for other cephalometric indicators used to determine lower incisor position. For instance, Ricketts' A–Pg line [1] is considerably affected by the maxillary reference, while Steiner's N–B [1] depends on the N and B points, both potentially modified by incisor inclination. Given these factors, the Lower Incisor–Pg may represent a more consistent and reliable index for clinical cephalometric evaluation, being insensitive to the Nasion and maxillary positions and more responsive to mandibular plane changes than IMPA.

Despite advancements in digital and three-dimensional imaging, cephalometric tracing continues to be indispensable in orthodontic diagnostics [27], especially with the integration of AI-based landmark detection [28]. Determining the anterior dental limit remains a key step in therapeutic planning [29]; therefore, Lower Incisor–Pg can serve as a useful supplementary measure for defining orthodontic movements and visualizing treatment objectives.

This study, however, presents certain limitations. Being retrospective, it assessed lower incisor positioning exclusively through cephalometric parameters, without integrating clinical tissue conditions. Clinicians should also account for factors such as gingival biotype and recession susceptibility when determining ideal tooth placement. Nonetheless, considering the exceptional sample size and its heterogeneity, the results provide valuable diagnostic guidance for orthodontic treatment planning.

Conclusion

- Within the examined population, the mean Lower Incisor–Pg measured 3.2 ± 4.0 mm, demonstrating no dependency on the mandibular plane angle.
- For every 1° increase in ANPg^ and SNGoGn^, the Lower Incisor–Pg rose by 0.45 mm and 0.36 mm, respectively.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: None

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