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Treatment Decision for Borderline Class III Malocclusion in Adults; Orthodontic Camouflage versus Orthodontic-Orthognathic Surgery

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Abstract

Objectives: Determining the optimal treatment approach for adult borderline Class III malocclusion, whether orthodontic camouflage or orthodontic-orthognathic surgery, remains clinically challenging. This study aimed to distinguish between these two treatment options using lateral cephalometric analysis.

Methods: Pretreatment lateral cephalograms of 60 adult patients with borderline Class III malocclusion were analyzed, comprising 30 patients in the camouflage group and 30 in the surgery group. The Mann-Whitney U test was used to compare cephalometric variables between the two groups. Stepwise discriminant analysis was employed to identify the variables that best differentiated the treatment groups. An equation was then generated using the canonical discriminant function coefficients of the selected variables and a constant to calculate a critical score for treatment categorization.

Results: Stepwise discriminant analysis identified four key variables and generated the following equation: Individual score = –13.684+0.138(SN)+0.312(Wits)+0.068 (L1-MP)+0.179(H angle). A critical score of 0 was established. Patients with scores above 0 were considered suitable for orthodontic camouflage, while those with scores below 0 were better suited for orthodontic-orthognathic surgery. The overall classification accuracy of the model was 86.7%.

Conclusions: Four cephalometric variables including SN length, Wits appraisal, L1-MP angle, and H angle were effective in distinguishing appropriate treatment modalities for adult borderline Class III malocclusion patients.

Keywords: borderline Class III malocclusion, cephalometric analysis, orthodontic camouflage, orthodontic-orthognathic surgery

Introduction

Class III malocclusion is one of the most challenging dentofacial deformities to correct in dental practice. Its etiology is multifactorial, involving a complex interaction between genetic, hereditary, and environmental factors.[1] The prevalence of Class III malocclusion varies across populations, with the highest reported prevalence of 15.8% found in Southeast Asian populations, and a lower prevalence observed among European and Caucasian groups. Class III malocclusion is typically characterized by a concave facial profile resulting from mandibular prognathism, maxillary retrognathism, or a combination of both-of which the combined form is the most common presentation.[2,3] Cephalometric characteristics in these patients often show a retruded but normally sized maxilla, and a protruded mandible with increased length. Additionally, the maxillary incisors tend to be proclined and buccally tipped, whereas the mandibular incisors are typically retroclined and lingually tipped.[4]

Accurate diagnosis and treatment planning are based on comprehensive clinical examinations, study models, cephalometric analysis, and radiographic imaging, along with careful assessment of dental and skeletal relationships.[5] In adult patients, treatment of Class III malocclusion generally follows one of two approaches: orthodontic camouflage or a combination of orthodontics and orthognathic surgery. The decision depends on several factors, including the patient's chief complaint and the severity of the skeletal discrepancy. Mild to moderate discrepancies can often be managed with orthodontic camouflage, whereas more severe cases typically require orthognathic surgery.[6] Additional considerations include the cost of treatment, the invasive nature of surgery, and the patient's overall health condition.[2] However, in borderline cases, where either treatment approach may be viable, treatment planning becomes particularly controversial. Many patients are unable or unwilling to undergo surgery due to medical, financial, or psychological constraints.

Numerous studies have explored treatment decision-making in Class III malocclusion. For instance, Eslami *et al.,*[5] recommended camouflage treatment in patients with a Holdaway angle greater than 10.3° and a Wits appraisal above -5.8 mm. Rabie *et al.*,[3] similarly used the Holdaway angle as a key variable, suggesting that values above 12° are indicative of successful camouflage treatment, while lower values favor surgical intervention Benyahia *et al*.,[7] proposed a lower threshold, identifying 7.2° as the borderline value for the Holdaway angle. Other researchers, such as Eisenhauer *et al*.,[8] developed predictive equations using variables like Wits appraisal, SN length, the maxillary/mandibular (M/M) ratio, and the lower gonial angle to identify critical scores for treatment categorization. Likewise, Kochel derived an equation using Wits appraisal, the M/M ratio, and the NSAr angle, producing a critical score of 0.251.[9]

Given the variability of proposed variables and cut-off values in previous studies, the objective of this study was to identify the most decisive cephalometric variables that can reliably differentiate between treatment groups in adult borderline Class III malocclusion patients. The study further aimed to develop a discriminant function that yields a critical score to guide clinical decision-making between orthodontic camouflage and orthodontic-orthognathic surgery.

Materials and Methods

Subjects and image acquisition

This research is a retrospective study that aims to identify treatment plans for borderline Class III malocclusion patients by using pretreatment lateral cephalograms. This study was approved by the Human Experimentation Committee of the Faculty (No. 47/2024). To calculate the required minimum sample size, a pilot study was performed. The sample size calculation was done using the G*Power software program (version 3.1.9.4, University of Kiel, Germany). Considering a power of 85% and a significance level of 5% and an effect size of 0.82, the final sample was composed of 30 subjects in each group. All participants were patients attending orthodontic treatment and requiring pretreatment lateral cephalograms for diagnosis and treatment plan.

The inclusion criteria were as follows:

1. Adults aged 18 or older with skeletal Class III malocclusion
2. No previous orthodontic treatment or orthodontic-orthognathic surgery treatment
3. ANB of 0° to –5.5°
4. Wits appraisal of –10.5 mm. to. -1 mm.
5. Overjet ≤0 before treatment

Patients with syndromic or medically compromised and maxillofacial trauma history were excluded from this study.

Patients were retrospectively selected from the records of the Department of Orthodontics, Faculty of Dentistry, between 2020 and 2023. After applying the inclusion and exclusion criteria, 70 patients with skeletal Class III malocclusion remained eligible. These patients were independently categorized into either the orthodontic camouflage group or the orthodontic–orthognathic surgery group by two board-certified orthodontists. Pretreatment records, including panoramic and lateral cephalograms, intraoral and extraoral photographs, and plaster study models, were evaluated. Based solely on these diagnostic materials, and considering patient-reported symptoms, facial esthetics, and the severity of dentoskeletal discrepancies, the orthodontists independently categorized patients into either the camouflage or surgical treatment group. The final decision also considered functional and esthetic aspects as well as patient preferences. According to the sample size calculation, 30 patients from each group were required. Therefore, 30 patients were randomly selected from each category, resulting in a total sample of 60 patients for analysis.

Methods

Each patient underwent lateral cephalometric radiography (NewTom Giano, Verona, Italy). Lateral cephalograms were taken at maximum intercuspation, with the lips in a rest position and the Frankfort horizontal plane aligned according to the natural head position. All lateral cephalograms were traced digitally using Dolphin imaging software version 11.9 (Dolphin Imaging & Management Solutions, Chatsworth, Calif). The following cephalometric tracings of landmarks were made on the pretreatment lateral cephalometric radiographs: S (Sella), N (Nasion), Go (Gonion), Gn (Gnathion), Pg (Pogonion), ANS (Anterior nasal spine), PNS (Posterior nasal spine), A (Subspinale), B (Supramentale), Me (Menton), Ar (Articulare), U6 (Upper first molar occlusal plane), L6 (Lower first molar occlusal plane), U1 tip (Upper central incisor tip), U1 root (Upper central incisor root apex), L1 tip (Lower central incisor tip), L1 root (Lower central incisor root apex), N' (Soft tissue nasion), Ls (Labrale superius) and Pg' (Soft tissue pogonion) (Figure 1).

The following linear, proportional, and angular measurements were calculated:

(1) SNA angle: The angle between the sella turcica (S), the nasion (N) and the point A

(2) SNB angle: The angle between the sella turcica (S), the nasion (N) and the point B

(3) ANB angle: The relationship between the maxilla and the mandible. This measurement is obtained from the equation ANB = SNA – SNB

(4) SN: An anteroposterior length of the anterior cranial base. It is measured from the Sella turcica (S) to the nasion (N)

(5) Wits appraisal: Length of the distance AO-BO; AO (intersection between a perpendicular line from Point A and the occlusal plane); BO (intersection between a perpendicular line from Point B and the occlusal plane)

(6) NAPg: The intersection of a line from the nasion (N) to point A and point A to the pogonion (Pg)

(7) NSAr or saddle angle: An angle formed by the nasion (N), sella turcica (S) and the articulare (Ar)

(8) SN-GoGn: Divergence of the mandibular plane (Go-Gn line) relative to the anterior part of the cranial base (SN line)

(9) Gonial angle (ArGoMe): The angle formed by the articulare (Ar), the gonion (Go) and the menton (Me)

(10) Go upper (ArGoN): The angle formed by the articulare (Ar), the gonion (Go) and the nasion (N)

(11) Go lower (NGoMe): The angle formed by the nasion (N), the gonion (Go) and the menton (Me)

(12) M/M ratio: A ratio of the anteroposterior length of the maxilla (ANS-PNS) to the anteroposterior length of the mandible according to Steiner's mandibular plane (Gn-Go)

(13) L1-MP angle: An angle between the long axis of mandibular central incisor and Steiner's mandibular plane (Gn-Go)

(14) U1-L1 or interincisal angle: An angle between long axis of maxillary central incisor and long axis of mandibular central incisor

(15) Holdaway angle (H angle): An angle formed by the soft tissue H line (line tangent to upper lip and soft tissue pogonion) and the soft tissue facial plane (N-Pg)

All the measurements were made by one participant who calibrated by experienced orthodontist. A total of 60 subjects' radiographs were traced and measured twice, four weeks apart, for intra-examiner reliability. The method error in measuring was calculated by the Dahlberg's formula $ME=\sqrt{\Sigma d^2/2n}$ where d is a difference between twice measurement and n is the number of double measurements.[10] Random linear errors ranged from 0.25 to 4.06 and errors in angular variables ranged from 0.01 to 2.09.

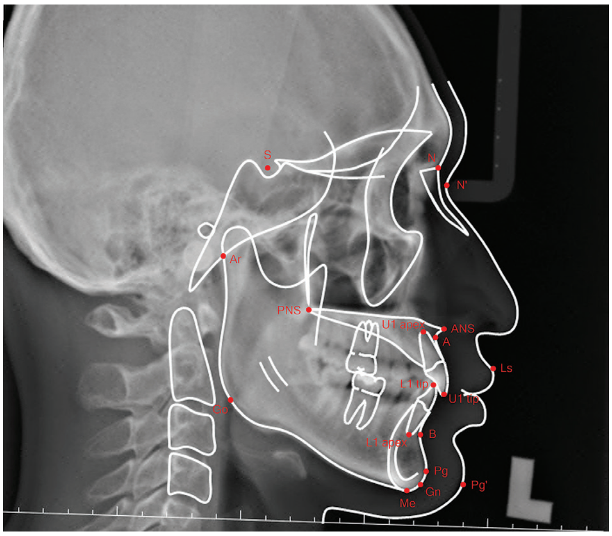

Figure 1: The lateral cephalometric reference points employed in this study included: sella (S); articulare (Ar); gonion (Go); menton (Me); pogonion (Pog); gnathion (Gn); Point B (B); root apex of the mandibular central incisor (L1 apex); incisal tip of the mandibular central incisor (L1 tip); incisal tip of the maxillary central incisor (U1 tip); root apex of the maxillary central incisor (U1 apex); Point A (A); anterior nasal spine (ANS); posterior nasal spine (PNS); nasion (N); labrale superius (Ls); soft tissue nasion (N') and soft-tissue pogonion (Pg').

Statistical analysis

Descriptive and analytical statistical analyses were conducted using SPSS (Statistical Package for the Social Sciences), version 22.0 for Windows (IBM Corp., Armonk, NY, USA). For each variable and group, the minimum, maximum, mean, standard deviation, and median values were calculated. Descriptive statistics were used to summarize the baseline characteristics of the participants (Table 1). The Shapiro-Wilk test was applied to assess the normality of data distribution. As some variables were not normally distributed, the Mann-Whitney U test was employed to compare variables between the two groups: the orthodontic camouflage group and the orthodontic–orthognathic surgery group. A significance level of $p<0.05$ was considered statistically significant (Table 2).

In this study, stepwise discriminant analysis was used to identify the cephalometric variable that best separates the orthodontic camouflage and orthodontic-orthognathic surgery group. The canonical discriminant function coefficients were calculated with a constant for each selected variable (Table 3). This resulted in a new equation that assigns a score to each patient. The critical score corresponds to the mean value of the group centroids for both groups. Then, the classification value was evaluated (Table 4).

Results

The overall sample included 60 patients who met the inclusion and exclusion criteria. The mean age of the patients was 30.7±2.9 years. There were 27 males (45%) with a mean age of 31.2±3.0 years and 33 females (55%) with a mean age of 30.3±2.7 years. Descriptive statistics of the orthodontic camouflage group and orthodontic–orthognathic surgery group are shown in Table 1.

The Mann-Whitney U test revealed significant differences ($p<0.05$) in seven variables between the two groups (Table 2). Significant intergroup differences were observed in variables related to the sagittal skeletal relationship, including SN, SNB, ANB, Wits appraisal, and NAPg. In contrast, variables such as SNA, NSAr, SN-GoGn, Ar-Go-Me, Ar-Go-N, and N-Go-Me did not show statistically significant differences between the orthodontic camouflage group and the orthodontic-orthognathic surgery group. Additionally, the M/M ratio was not effective in distinguishing between the two groups. Regarding dental relationships, a significant difference was observed in the angle between the long axis of the mandibular central incisor and the mandibular plane (L1-MP), whereas the interincisal angle (U1-L1) did not differ significantly between groups. Additionally, a significant difference was found in the soft tissue profile, as indicated by the H angle.

According to Stellzig *et al.*,[8] discriminant analysis has been applied to determine the dentoskeletal variables that separate surgical from nonsurgical orthodontic patients. Using stepwise discriminant analysis, four highly significant variables were identified: SN, Wits appraisal, L1–MP, and H angle. The canonical discriminant function coefficients of the selected variables, along with a calculated constant, resulted in an equation that provides individual scores to categorize patients into the groups (Table 3).

Individual score = –13.684+0.138(SN)+0.312(Wits)+0.068(L1-MP)+0.179(H angle)

Table 1: Descriptive statistics (mean, standard deviation, median, minimum, and maximum) of cephalometric variables in the orthodontic camouflage group and the orthodontic-orthognathic surgery group.

Cephalometric variables	Orthodontic camouflage group (N=30)					Orthodontic-orthognathic surgery group (N=30)				
	Min	Max	Mean	SD	Median	Min	Max	Mean	SD	Median
SNA (°)	71.7	88.4	79.4	3.8	79.3	73.0	91.0	80.9	4.3	79.1
SNB (°)	75.1	88.6	81.7	3.5	81.4	74.2	92.0	84.2	4.3	83.3
ANB (°)	-4.2	-0.2	-2.3	1.0	-2.2	-5.0	-0.9	-3.3	1.3	-4.0
SN (mm)	57.0	67.5	60.8	2.5	60.3	42.5	66.8	57.7	6.7	59.0
Wits appraisal (mm)	-9.8	-3.2	-6.2	1.7	-6.3	-10.3	-2.7	-7.9	2.1	-8.7
NAPg (°)	-9.5	3.8	-3.8	3.0	-4.1	-11.3	0.9	-7.2	3.7	-9.0
NSAr (°)	110.4	128.6	117.1	4.4	117.0	112.1	129.1	117.2	4.4	115.8
SN-GoGn (°)	26.6	39.3	32.9	3.7	34.1	24.9	48.1	35.5	5.5	35.1
ArGoMe (°)	111.6	140.2	126.2	6.0	125.1	108.1	138.7	126.4	7.0	125.8
ArGoN (°)	40.8	53.2	46.3	2.9	46.6	40.1	52.7	45.5	3.3	45.6
NGoMe (°)	73.5	93.0	80.4	5.4	79.5	68.7	93.1	81.2	7.0	80.1
M/M ratio (%)	0.5	0.7	0.6	0.0	0.6	0.5	0.6	0.5	0.0	0.5
L1-MP angle (°)	72.0	96.9	87.4	5.0	88.8	69.9	97.8	77.9	6.9	76.4
Interincisal angle (°)	111.5	142.7	128.6	7.5	127.8	113.0	154.2	132.9	8.8	131.9
H angle (°)	9.0	17.4	13.7	2.5	14.1	2.2	17.3	9.2	3.4	8.6

Table 2: Significant differences between orthodontic camouflage group and orthodontic-orthognathic surgery group.

Cephalometric variables	Mann-Whitney test
SNA	0.329
SNB	0.019*
ANB	0.002*
SN	0.008*
Wits	0.0005*
NAPg	0.001*
NSAr	0.976
SNGoGn	0.059
ArGoMe	0.751
ArGoN	0.399
NGoMe	0.663
M/M ratio	0.149
L1-MP	0.000001*
Interincisal	0.059
H angle	0.000003*

*p<0.05

Table 3: Stepwise discriminant analysis.

Predictive variable	Canonical Discriminant Function Coefficients
SN	0.138
Wits	0.312
L1-MP	0.068
H angle	0.179

Individual score = -13.684+0.138SN+0.312Wits+0.068L1-MP+0.179H angle

Group centroid: camouflage group 1.225, surgery group –1.225 Critical score=0

Table 4: Classification result.

Original group membership	Predicted group membership	
	Orthodontic camouflage group	Orthodontic-orthognathic surgery group
Orthodontic camouflage group (n=30)	93.3% (n=28)	6.7% (n=2)
Orthodontic-orthognathic surgery group (n=30)	20.0% (n=6)	80.0% (n=24)

Sensitivity (require orthodontic-orthognathic surgery): 0.8; Specificity (correct Class III malocclusion by orthodontic camouflage): 0.93; overall accuracy: 0.867

The critical score was 0, representing the mean value of the group centroids for both groups. Each Class III malocclusion patient with an individual score above the critical score will be treated successfully by orthodontic camouflage. On the other hand, Class III malocclusion patients with an individual score below the critical score should undergo orthodontic-orthognathic surgery. The percentage of patients correctly classified by the equation was 86.7%. Two patients in the orthodontic camouflage group and six patients in the orthodontic–orthognathic surgery group were misclassified, as the discriminant equation assigned them to the opposite treatment group compared with the actual treatment received. These misclassifications underscore the limitation that, although the model showed high sensitivity (0.80) and specificity (0.93), not all cases can be perfectly distinguished (Table 4).

Discussion

The optimal treatment for borderline Class III malocclusion remains a topic of debate, as both orthodontic camouflage and orthognathic surgery are viable options. Camouflage is typically indicated for mild to moderate dentoalveolar discrepancies, whereas surgery is preferred for more severe skeletal issues.[8] Treatment decisions should consider not only cephalometric parameters but also patient esthetic concerns and expectations. Advances in appliances and biomechanics have expanded the scope of camouflage, offering less invasive alternatives. However, in cases of pronounced skeletal discrepancy, camouflage may compromise esthetic or functional outcomes, making surgery the more appropriate and stable long-term option. Treatment decisions for borderline Class III malocclusion patients are influenced by multiple factors. Key considerations include the patient's chief complaint[11], which guides clinical goals, and diagnostic tools such as study models[12] and cephalometric analysis[13] that assess skeletal and dental relationships.[14] Patient preferences, particularly concerns about surgery, and socioeconomic factors, such as cost, also play important roles. While orthodontic camouflage may appeal to those seeking non-invasive options, surgery remains necessary for more severe discrepancies. Lastly, effective communication and individualized assessment are essential for selecting the most appropriate treatment approach.

The inclusion criteria for this study were carefully defined to ensure that the sample represented borderline skeletal Class III patients for whom treatment decisions between orthodontic camouflage and orthodontic–orthognathic surgery are most critical. First, only adults aged 18 years or older were included to avoid the influence of residual craniofacial growth and to ensure that skeletal discrepancies reflected stable conditions. Second, patients with no history of orthodontic or surgical treatment were selected so that baseline cephalometric measurements would not be influenced by prior interventions. Third, the ANB angle range of 0° to –5.5° was chosen to capture mild to moderate skeletal Class III cases, which often present the greatest clinical uncertainty in treatment planning. Fourth, a Wits appraisal between –10.5 mm and –1 mm was applied to provide an additional sagittal assessment that is less affected by cranial base variations, while excluding extremely severe discrepancies requiring surgery in all cases. Finally, patients were required to present with an overjet of ≤0 mm, thereby confirming the incisor relationship characteristic of skeletal Class III malocclusion and ensuring diagnostic consistency across the study group.

Stepwise discriminant analysis is a statistical method used in classification problems, particularly when the goal is to predict a categorical outcome. It is a variation of discriminant analysis, in which predictors are evaluated and selected in a stepwise manner to find the most significant variables that best explain the variation between the category's groups.[15] According to Stellzig, Stepwise discriminant model was used and generated 4-variable model to distinguish treatment modalities in Class III malocclusion patients which are Wits appraisal, SN, M/M ratio and lower gonial angle.[8] In Kochel's study, the degree of laterognathism was added to the model and give the result as increased in predictability for the surgical group.[9] Nevertheless, discriminant models have limitations: difficulty in identifying precise landmarks, potential omission of relevant variables, the need for large sample sizes for external validity, and reduced accuracy when group differences are subtle.[8] For present study, stepwise selected variables were SN, Wits appraisal, L1-MP and H angle. The classification power of the equation was 86.7%. Compared to the study of Stellzig, the predictive power was 92% with a greater number of sample (non-surgery group=87 patients, surgery group=88 patient).[8] In further study, relatively large samples may be needed to increase the discriminant power of the model.

The first variable extracted from the discriminant model was SN length. Meta-analysis by Gong[16] showed that anterior cranial base length was significantly smaller in Class III malocclusion than in Class I and Class II malocclusions. According to Stellzig[8], the discriminant analysis presented the different in anterior cranial base length between non-surgery and surgery group with greater SN length value in non-surgery group. However, Polat found no significant difference in anterior cranial base lengths between Class III malocclusion and normal occlusion.[17]

The second variable that best separate the treatment option of Class III malocclusion patients was Wits appraisal. According to Jacobson[18], Wits appraisal represented the severity of the anteroposterior jaw relationship. The functional occlusal plane was used as a reference for defining the relationship of the jaw. Therefore, the rotation of the cranial base will not affect the degree of jaw disharmony. Despite the precise landmark of Wits appraisal cannot clearly identified in cephalometric radiograph[7], the present study used the same investigator tracing all the radiographs to minimize the systemic error of interobserver measurement. The mean Wits appraisal value indicating a Class I skeletal relationship in the Thai population is –2.4±1.7 mm[19],whereas the values in Caucasians are –1.17±1.9 mm for males and –0.1±1.77 mm for females.[18] Previous studies by Stellzig[8] and Kochel[9] identified the Wits appraisal as the primary variable in their discriminant models to differentiate between non-surgical and surgical treatment groups. In contrast to using a discriminant function, simpler approaches such as Wits appraisal thresholds can also aid in treatment decisions. Eslami *et al.*,[5] proposed a cut-off of –5.8 mm, above which camouflage is likely to succeed, and below which surgery is more appropriate. While simpler and easier to apply, this method may lack the nuance provided by multivariate models. Nevertheless, clinicians may consider using Wits appraisal in combination with other variables in settings where full cephalometric evaluation is not feasible. Furthermore, Tseng[20] reported that a Wits appraisal below –11.18 mm was one of six criteria indicating the need for orthognathic surgery in Class III malocclusion patients.

The third variable entering the discriminant model was H angle, which is formed by the soft tissue H line and the soft tissue facial plane. Thai normal range of H angle is 15.27°±2.73°[21], while in the present study mean value H angle of non-surgery groups is 13.7° and surgery groups is 9.2°. In the literature, several studies have investigated the influence of soft tissue profile on treatment plan decisions. According to Eslami[5], borderline Class III malocclusion patients with H angle greater than 10.3° would be treated successfully by orthodontic camouflage, while patients with H angle less than 10.3° should be treated by orthodontic-orthognathic surgery. As for Rabie[3] and Benyahia[7], these studies reported this critical H angle score as 12° and 7.2° respectively. Although the critical score for the H angle varies across studies, numerous investigations have consistently demonstrated its efficacy as a discriminative variable in distinguishing between orthodontic camouflage and surgical treatment groups. As the H angle represents the soft tissue profile, it is frequently a pivotal determinant influencing patients' decisions to seek orthodontic treatment, reflecting concerns regarding facial esthetics.

Another variable demonstrating significant intergroup differences was the L1-MP angle. In this study, the mean L1-MP angles were 87.4° in the non-surgery group and 77.9° in the surgery group, both notably smaller than the reported Thai normative value of 90.1°±8.7°.[22] These findings indicate a pronounced retroclination of mandibular incisors, particularly among patients who required surgical intervention. The lower limits for incisal movement to effectively compensate for Class III skeletal discrepancies are acknowledged as approximately 80° relative to the mandibular plane.[23] Therefore, patients whose mandibular incisors approach or surpass these limits may not achieve optimal outcomes through orthodontic camouflage alone, highlighting the significance of carefully assessing the degree of dental compensation during treatment planning. According to Tseng[20], the study found L1-MP to be the best diagnostic variable for determining treatment modalities for Class III malocclusion patients. The study suggested that borderline Class III malocclusion patients with L1-MP greater than 80.8° would be successfully treated by orthodontic camouflage. In general, mandibular incisors are relatively retroclined, while maxillary incisors are typically proclined to compensate for the skeletal discrepancy in Class III malocclusion. However, in severe Class III cases, patients exhibit a negative overjet in the incisor relationship, despite the compensatory inclination of both maxillary and mandibular incisors. The importance of L1-MP lies in the fact that patients with severely retroclined mandibular incisors prior to treatment may not achieve successful outcomes through orthodontic camouflage alone, due to anatomical limitations. Moreover, the stability of the post-treatment results may be compromised.

Population-specific variations are critical in interpreting cephalometric variables. In this Thai sample, the average SN length and Wits appraisal differed from Caucasian norms, consistent with Gong *et al*.,[16] and Chaiworawitkul's[19] reports, underscoring the need for localized data. The L1-MP angle was more retroclined than Thai normative values[22], reflecting compensatory dental patterns in Class III cases, while the H angle showed marked variability compared with other populations[24], highlighting the influence of ethnicity and cultural perceptions on soft-tissue esthetics. Beyond anatomical differences, treatment planning for Asian patients must also account for cultural and esthetic considerations. Asian populations often present with unique craniofacial characteristics such as a tendency toward bimaxillary protrusion[25], wide and prominent jaw structure compared with Caucasian populations.[26] These features can influence both cephalometric interpretations and the threshold for determining between orthodontic camouflage and orthognathic surgery.

Currently, there is no standardized protocol for selecting camouflage versus surgical treatment in borderline skeletal Class III malocclusion, making the issue controversial.[5] Camouflage is often used in adolescents and adults with mild to moderate discrepancies[27], particularly when surgery is not acceptable to the patient. This approach, involving maxillary incisor proclination and mandibular incisor retroclination, improves occlusion but does not correct the skeletal problem[23], and some patients later pursue surgery due to dissatisfaction.[28] In the context of Asian patients, these considerations become especially important. Esthetic ideals in many Asian cultures emphasize facial harmony and soft-tissue balance, which may increase the preference for surgical treatment to optimize facial profile improvement. Accordingly, the findings of the present study are particularly relevant to Asian patients, as they provide population-specific evidence to guide individualized treatment planning. Future studies comparing outcomes across different ethnic groups will be valuable in confirming the applicability of these results beyond Asian populations.

This study has several limitations. First, the sample size was relatively small (N=30 per group), which may affect the statistical power and generalizability. Second, although a digital cephalometric tracing program was utilized, human error in measurements remains a potential source of inaccuracy. To minimize this, each radiograph was traced twice by the same investigator with a one-month interval between tracings. The two variables with the highest method error were the interincisal angle and the NSAr angle. Method error in interincisal angle could be due to superimposition of both maxillary and mandibular central incisors in lateral cephalometric radiograph. The NSAr angle showed intra-observer variability, possibly due to the difficulty in identifying the Sella point, which is a constructed landmark lacking a definitive anatomical reference. Third, the retrospective design restricted the ability to control for potential confounding variables, and factors such as patient preferences, chief complaint, and socioeconomic status–important in treatment decision-making–were not included in the analysis. Lastly, as a single-center study, the findings may not be broadly generalizable. Future multi-center research with larger, more diverse populations and additional variables such as soft tissue profile and long-term outcomes is recommended to enhance the robustness and applicability of the predictive model.

Conclusions

Among the 15 cephalometric variables analyzed, four were found to be the most effective in distinguishing between patients treated with orthodontic camouflage and those who underwent orthodontic-orthognathic surgery. These significant variables are SN length (cranial base length), Wits appraisal (sagittal jaw relationship), L1-MP (lower incisor to mandibular plane angle), and H angle (facial esthetics). The canonical discriminant function coefficients of these variables, along with a calculated constant, generate an equation that yields a critical score. This critical score effectively categorizes patients into the appropriate treatment group.

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Conflict of Interest

The authors declare no conflict of interest.

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