Extraction Decision-Making Wigglegram

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The decision whether to extract teeth is one of the most critical and controversial in orthodontic treatment, depending to a large extent on each clinician's personal experience. The main reasons for extractions are well recognized: crowding, dentoalveolar protrusion, the need for facial profile alteration, and mild anteroposterior maxillary discrepancies.[1] In borderline cases, however, there can be considerable disagreement.[2]

According to Buchin, a case is borderline when extraction of permanent teeth is required to reach a stable and functional occlusion, but when the patient has good facial esthetics that could be disturbed by extractions.[3] We have found that borderline cases also have the following characteristics:

- Absence of dental or craniofacial anomalies.
- Permanent dentition.
- Healthy periodontium.
- Normal anteroposterior relationship between maxilla and mandible (skeletal Class I).

The wigglegram or "standard-deviation diagram" was first adapted for orthodontic use by Vorhies and Adams[4] to facilitate the interpretation of Downs's cephalometric analysis.[5] We have developed a wigglegram that can be used to help make extraction decisions in borderline cases (Fig. 1).

The vertical central line represents the norms of the various measurements. Any values to the left or right of the central line are either above or below the average. The largest and the smallest acceptable values were plotted to pro-

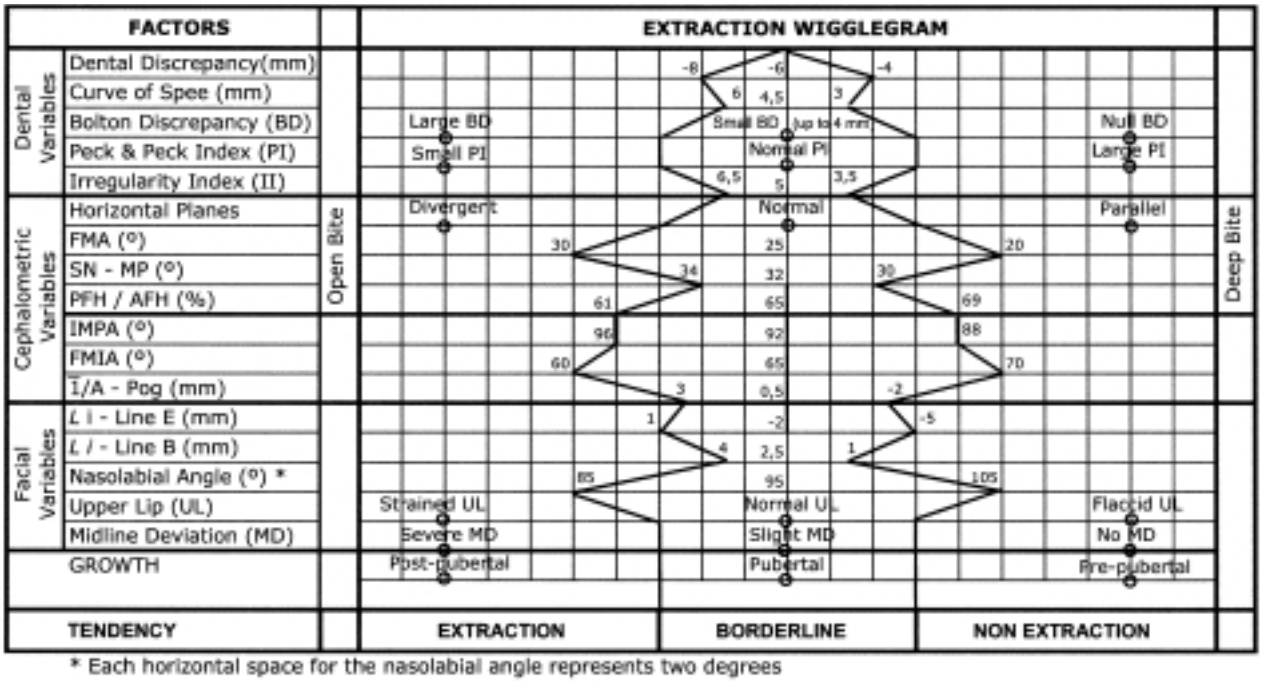

Fig. 1 Extraction decision-making wigglegram.

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duce the zigzag lines of the wigglegram, which thus depicts the parameters of a borderline malocclusion. Conditions that favor extractions are on the left side, and conditions weighing against extractions on the right.

The 18 factors, selected after an extensive literature review, are mostly numeric values expressed in degrees, millimeters, or percentages. Each horizontal increment corresponds to one unit, except for the nasolabial angle, where the scale is 2° due to the higher standard deviation.

Dental Variables

The dental factors can be evaluated using the patient's study casts. There are five variables:
Dental discrepancy. Crowding of 4-8mm can be treated with or without extraction.[6-9] A discrepancy greater than 8mm indicates a need for extraction, because conservative approaches such as stripping will probably be inadequate.
Curve of Spee. Accurate measurement of this curve can be tricky. First, the clinician should place a rigid rectangular object such as a floppy disk on top of the occlusal surface on the lower dental cast (Fig. 2). Then, the greatest distance between the cusp tips of the posterior teeth and the object should be measured on each side with a caliper.[10] A curve of Spee of 3-6mm (1.5-3mm per side) is considered mild,[11] whereas a curve greater than 6mm is considered severe.[10] A borderline patient with a deep curve of Spee is likely to require extraction.

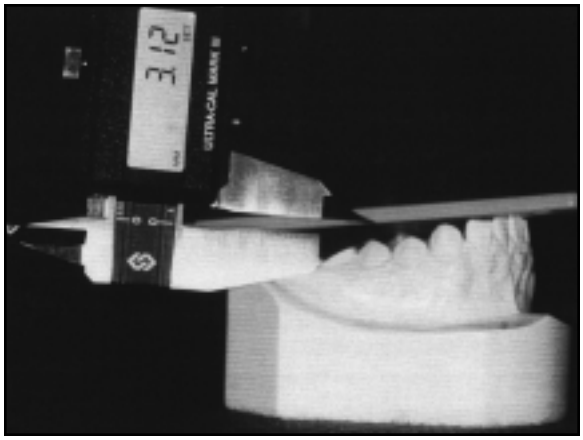

Fig. 2 Measurement of curve of Spee.

Bolton discrepancy. An interarch tooth-size discrepancy may be as good a reason for extraction as an intra-arch discrepancy.[6,12-14] A Bolton discrepancy[15] greater than 4mm is considered severe and may indicate extraction to adjust the interarch dental relationships. A discrepancy of as much as 4mm can be resolved by stripping or other conservative approaches.[16]
Peck & Peck Index. In planning treatment for patients with crowding, some orthodontists pay attention to the mesiodistal dimensions of the teeth and forget to analyze their shape as a whole. Peck and Peck, finding that crowded lower incisors were much wider mesiodistally than buccolingually, proposed an index for assessing shape deviations of the mandibular incisors.[17] To calculate the index, the greatest mesiodistal crown dimension is divided by the greatest buccolingual crown dimension (located near the gingival margin), and the result is multiplied by 100. An index between 88 and 95 indicates a good anatomical shape. On the other hand, an index greater than 95 indicates that the mesiodistal width of the tooth is much greater than the buccolingual width. Stripping can improve the shape of these teeth and gain space in the mandibular arch. Borderline patients with narrow lower incisors (index less than 88) are not candidates for stripping and, therefore, are more likely to need extraction.[17]
Irregularity Index. The Irregularity Index (II) was proposed by Little to evaluate mandibular incisor alignment.[18] It is obtained by adding the linear distances between the five adjacent ana-

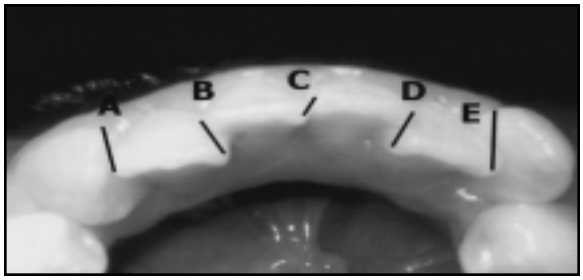

Fig. 3 Irregularity Index (II) obtained by adding linear distances between five adjacent anatomical contact points of lower anterior teeth (II = A + B + C + D + E).

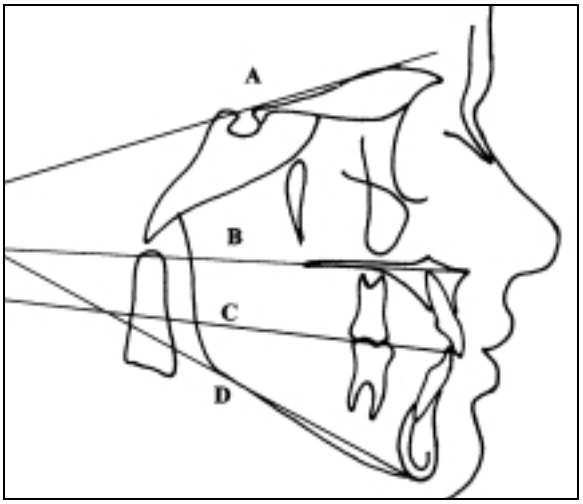

Fig. 4 Horizontal relationship of supra-orbital (A), palatal (B), occlusal (C), and mandibular (D) planes reflects vertical proportionality of craniofacial skeleton. This example shows normal relationship of planes.

tomical contact points of the lower anterior teeth (Fig. 3). Thus, the score will be 0 if the patient has perfectly aligned incisors and canines. An II of 3.5-6.5mm indicates mild irregularity. An index greater than 6.5mm indicates severe irregularity and a greater need for extraction.[18-20]

Cephalometric Variables

The first four cephalometric factors evaluate the vertical facial proportion; the other three focus on the position of the lower incisors, since proclination of these teeth is one of the main reasons for extraction.[21]

Relationship of the horizontal planes. According to Sassouni, the horizontal relationship of the supra-orbital, palatal, occlusal, and mandibular planes reflects the vertical proportionality of the craniofacial skeleton[22] (Fig. 4). Highly divergent planes indicate a skeletal open bite, which, in turn, favors extraction. Conversely, parallel horizontal planes indicate a skeletal deep bite, which does not favor extraction.

Frankfort mandibular plane angle (FMA). The normal value for the angle formed by the intersection of the Frankfort and mandibular planes is 200-300°. Patients with skeletal deep bite usually have an FMA of less than 20°, whereas an FMA greater than 30° is associated with skeletal open bite.[23]

SN-mandibular plane angle (SN-MP). According to Schudy, the normal value of this angle is 300-340°.[24] The SN-MP angle, which is closely related to the FMA, provides another appraisal of the vertical balance of the face.

Proportion of posterior facial height to anterior facial height (PFH/AFH). This ratio was proposed by Jarabak and Fizzel to evaluate the vertical equilibrium of the craniofacial skeleton.[25] The PFH (distance between sella and gonion) is divided by the AFH (distance between nasion and menton). The normal value is 61-69%. Less than 61% suggests a skeletal open bite; greater than 69% indicates a skeletal deep bite.[22]

Incisor mandibular plane angle (IMPA). This angle was proposed by Margolis to evaluate the inclination of the lower incisor to the mandibular plane.[26] According to Tweed, IMPA can vary between 85° and 95°,[23] but its value is highly influenced by the mandibular plane inclination and the patient's ethnicity. Due to functional and esthetic impairment, an IMPA greater than 96° is an indication for extraction.[5,23]

Frankfort mandibular incisor angle (FMIA). The norm for the angle formed by the intersection of the Frankfort plane and the long axis of the lower incisor is 60-70°.[23] A value less than 60° indicates proclination of the lower incisors, whereas a value greater than 70° suggests that the lower incisors are retroclined.

Distance between the lower incisor and the A-Pog line (1/A-Pog). Proclination of the lower incisors can also be assessed by measuring the distance from the incisal edge of the most prominent mandibular incisor to the line connecting point A to pogonion. A negative value indicates

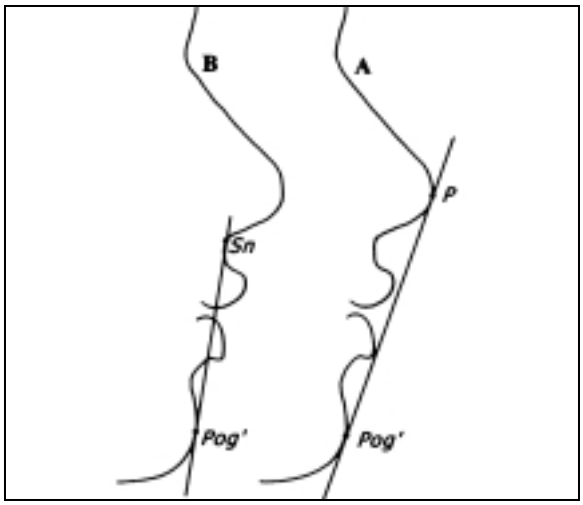

Fig. 5 A. E line connects pronasale (P) to soft-tissue pogonion (Pog'). B. B line connects subnasale (Sn) to Pog'.

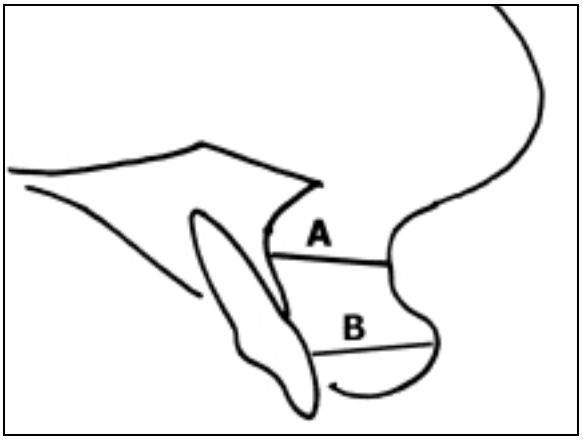

Fig. 6 To evaluate lip strain, thickness of upper lip should be measured in two areas: A. 3mm below skeletal point A. B. From vermillion border to labial surface of maxillary central incisors.

that the lower incisor is behind the A-Pog line. Values between –2mm and 3mm indicate a good sagittal position of the lower incisors.[27]

Facial Variables

The facial esthetics of borderline patients can be adversely affected by orthodontics if only dental and skeletal standards are used in treatment planning. The importance of the soft tissues in determining the final balance of the profile has been extensively documented.[28-31] Therefore, five factors were included in the wigglegram:

Distance between the E line and the lower lip (Li). The E line is drawn from the tip of the nose to soft-tissue pogonion[32] (Fig. 5A). Normally, the lower lip (here represented by the labrale inferius) is about 2mm behind this reference line, but because there is considerable variation in terms of age and sex, a standard deviation of 3mm was admitted by Ricketts.[32] As a result, values between –5mm and +1mm are considered normal, while values greater than +1mm indicate lower lip prominence. Since an esthetically pleasing face can be disrupted by lip protrusion, extraction is usually required in such cases.[14,33]

Distance between the B line and the lower lip (Li). According to Burstone, the lower lip should be 2.5 ± 1.5mm anterior to the B line, which connects the point where the columella meets the upper lip (subnasale) and soft-tissue pogonion[34] (Fig. 5B). Extraction is indicated if the lower lip is more than 4mm ahead of this line.

Nasolabial angle. This angle is formed by the intersection of the columella tangent and the upper lip tangent. There is a great deal of controversy regarding its normal value, but most authors choose numbers between 85° and 105°.[35-39] According to Drobocky and Smith, extraction of four bicuspids increases the nasolabial angle by an average of 5.2°.[37] Therefore, extraction should be avoided in patients with obtuse nasolabial angles (greater than 105°).

Upper lip morphology (UL). Holdaway's soft-tissue analysis includes a linear measurement to assess upper lip morphology and strain.[39] The thickness of the upper lip should be measured in two different areas: 3mm below skeletal point A, and from the vermillion border to the labial surface of the maxillary central incisors (Fig. 6). In normal patients, these two measurements should be approximately the same (± 1mm). If the vermillion border is thinner than the upper lip near point A, the lips are considered strained. If the upper lip is thinner than the vermillion border, the lips are considered flaccid. In borderline patients with strained lips, the incisors can be retracted without altering the soft-tissue profile, because the lip needs to reach normal form and thickness before retraction.[39] In such patients, extraction is indicated. On the other hand, the lips would immediately follow tooth movement in borderline patients with normal lips. According to Arnett and Bergman, orthodontists should avoid extraction in patients with flaccid lips due to the lack of labial support and the potential for

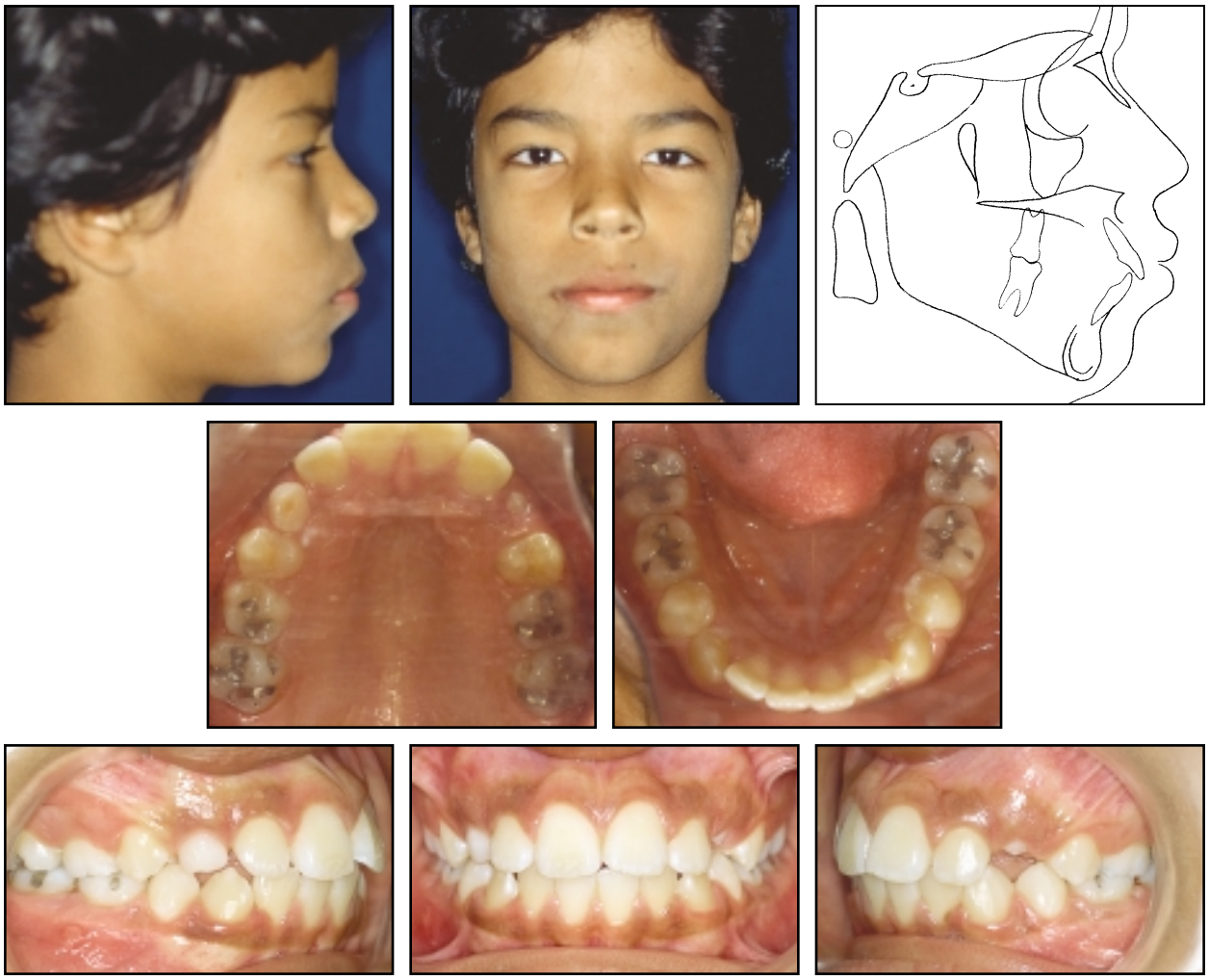

Fig. 7 Case 1. 12-year-old male patient with prominent lips before treatment.

esthetic problems.[29]

Dental midline deviations (MD). Using a piece of dental floss as a plumb line, the clinician can evaluate the alignment of the midline structures (nasal bridge, nasal tip, philtrum, upper dental midline, lower dental midline, and chin). Dental midline deviations due to skeletal problems should be managed surgically, but patients with a normal relationship of the facial midpoints can be treated orthodontically. Therefore, severe dental midline deviations support extraction.[29]

Growth Status

Growth of the soft and hard tissues has a significant influence on the facial results of orthodontic treatment. For example, a gross facial imbalance could be caused by additional growth of the nose after appliance removal. Therefore, extraction must be considered cautiously in patients with considerable remaining growth potential (pre-pubertal and pubertal patients). On the other hand, because further growth is unlikely to alter the facial profile of adult patients,[40] the extraction decision is safer in post-pubertal patients.

Case 1

A 12-year-old male presented for treatment due to his parents' complaint of lip prominence (Fig. 7). Clinical evaluation revealed a convex profile and a Class I malocclusion in the late mixed dentition. The lower lip was 9mm ahead of the E line and 12mm ahead of the B line. The upper lip was strained because of the proclined upper incisors. The thickness of the vermillion border was 14.5mm, while the upper lip thickness near point A was 17mm.

Cephalometric evaluation showed a Class I intermaxillary relationship (ANB = 3°). The lower incisors were proclined (IMPA = 99°), and

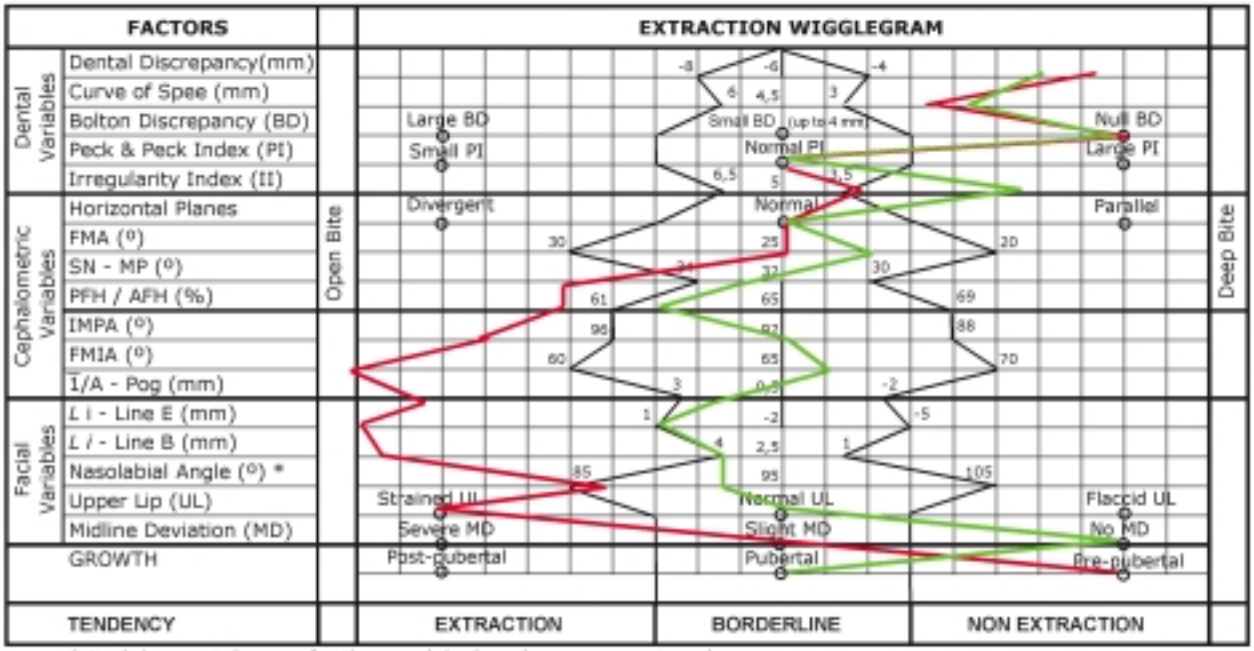

Fig. 8 Case 1. Extraction decision-making wigglegram (red = before treatment; green = after treatment).

the mandibular plane angle was high (SN-MP = 37°). Cast analysis indicated a positive dental discrepancy (+1mm) and a mild curve of Spee (+1mm). Because the lower second premolars had not yet erupted, their mesiodistal dimensions were estimated by using the Moyers predictive table.

Although most of the dental variables were outside the norms on the nonextraction side, the cephalometric and facial variables favored extraction (Table 1, Fig. 8). The decision was made to extract the four first premolars to improve the patient's lip position. The patient was also instructed to use a high-pull headgear for optimal retraction of the anterior teeth during space closure. Combined with the premolar extractions, this was effective in controlling the patient's vertical growth tendency.

After 30 months of orthodontic treatment, the facial improvement was evident in the patient's straight profile (Fig. 9). The SN-MP angle was reduced to 33° (Table 1), the PFH/AFH proportion was normal (62%), lower incisor inclination (IMPA) decreased by 7°, and the distance between the most prominent lower incisor and A-Pog was reduced to a normal value (+1.5mm). As a result, the lower lip was in a good relationship with lines E and B. Most of the cephalometric and facial factors were within the wigglegram's normal limits at the end of treatment (Fig. 8).

TABLE 1
CASE 1

	Pretmt.	Post-Tmt.
Dental discrepancy	+1mm	0mm
Curve of Spee	+1mm	0mm
Bolton discrepancy	Null	Null
Peck & Peck Index	Normal	Normal
Irregularity Index	3.3mm	0mm
Horizontal planes	Normal	Normal
FMA	25°	23°
SN-MP	37°	33°
PFH/AFH	60%	62%
IMPA	99°	92°
FMIA	55°	66°
1/A-Pog	+9mm	+1.5mm
Li-Line E	+8mm	+1mm
Li-Line B	+12mm	+4mm
Nasolabial angle	87°	92°
Upper lip morphology	Strained	Normal
Midline deviation	Lower midline 2mm right	Normal
Growth	Pre-pubertal	Pubertal

Although this patient could have been treated without extraction, his chief complaint would not have been resolved. Plotting the wigglegram helped us make the appropriate treatment decision.

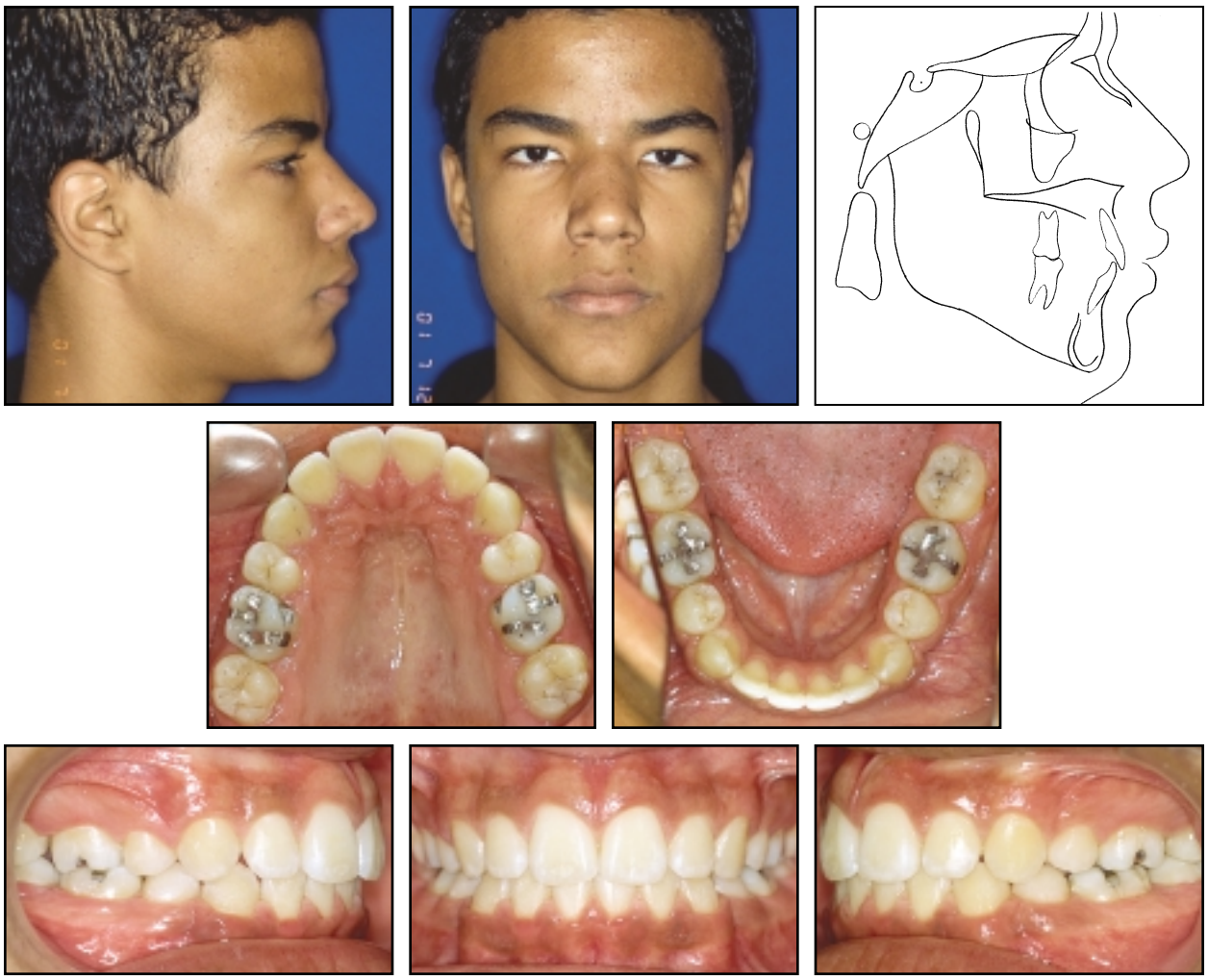

Fig. 9 Case 1. After four premolar extractions and 30 months of treatment.

Case 2

An 11-year-old female presented with the chief complaint of her dental malocclusion (Fig. 10). She demonstrated a straight profile, with the lower lip in an acceptable position according to the E line (+1mm) and the B line (+4mm). The upper lip was not strained, and the IMPA was normal by Brazilian standards (92°). The relationship between maxilla and mandible was also normal (ANB = 2°), but the cephalometric evaluation showed a vertical growth pattern, which would favor extraction (Table 2).

Clinical examination revealed an edge-to-edge relationship of both the first molars and the canines. The overbite was deep, and the overjet was 3mm. The dental discrepancy was positive (+1.5mm), the lower incisors were slightly irregular (II = 2.5mm), the four lower incisors were large (Peck & Peck Index > 100), and the curve of Spee was mild (1.5mm).

Although important cephalometric variables such as the divergent horizontal planes, the SN-MP angle, the PFH/AFH proportion, and the 1/A-Pog distance indicated extraction, most of the dental and facial variables were leaning

toward nonextraction (Fig. 11). No teeth were extracted, and a high-pull headgear was used to control the skeletal open bite during orthodontic treatment. The upper and lower incisors were stripped interproximally to gain some space for retraction.

Treatment time was 30 months (Fig. 12). The post-treatment wigglegram clearly showed that the dental malocclusion was treated with no adverse effect on the cephalometric measurements (Fig. 11). In fact, the beneficial effects of treatment on the facial profile were accompanied by a decrease in the 1/A-Pog distance, as well as a slight decrease in the distance between the lower lip and the E line (Table 2).

A key to treatment planning of this patient was the large Peck & Peck Index of the four lower incisors, which favored a conservative nonextraction approach. After reshaping of the four lower incisors by interproximal stripping, the index was normal. If the patient had presented with narrow lower incisors, she would not have been a candidate for stripping, and extrac-

TABLE 2
CASE 2

	Pretmt.	Post-Tmt.
Dental discrepancy	+1.5mm	0mm
Curve of Spee	+1.5mm	0mm
Bolton discrepancy	Null	Null
Peck & Peck Index	Large	Normal
Irregularity Index	2.5mm	0mm
Horizontal planes	Divergent	Divergent
FMA	27°	25°
SN-MP	38°	39°
PFH/AFH	60%	60%
IMPA	92°	92°
FMIA	62°	63°
1/A-Pog	+7mm	+3mm
Li-Line E	+1mm	0
Li-Line B	+4mm	+4mm
Nasolabial angle	95˚	93˚
Upper lip morphology	Normal	Normal
Midline deviation	Normal	Normal
Growth	Pubertal	Pubertal

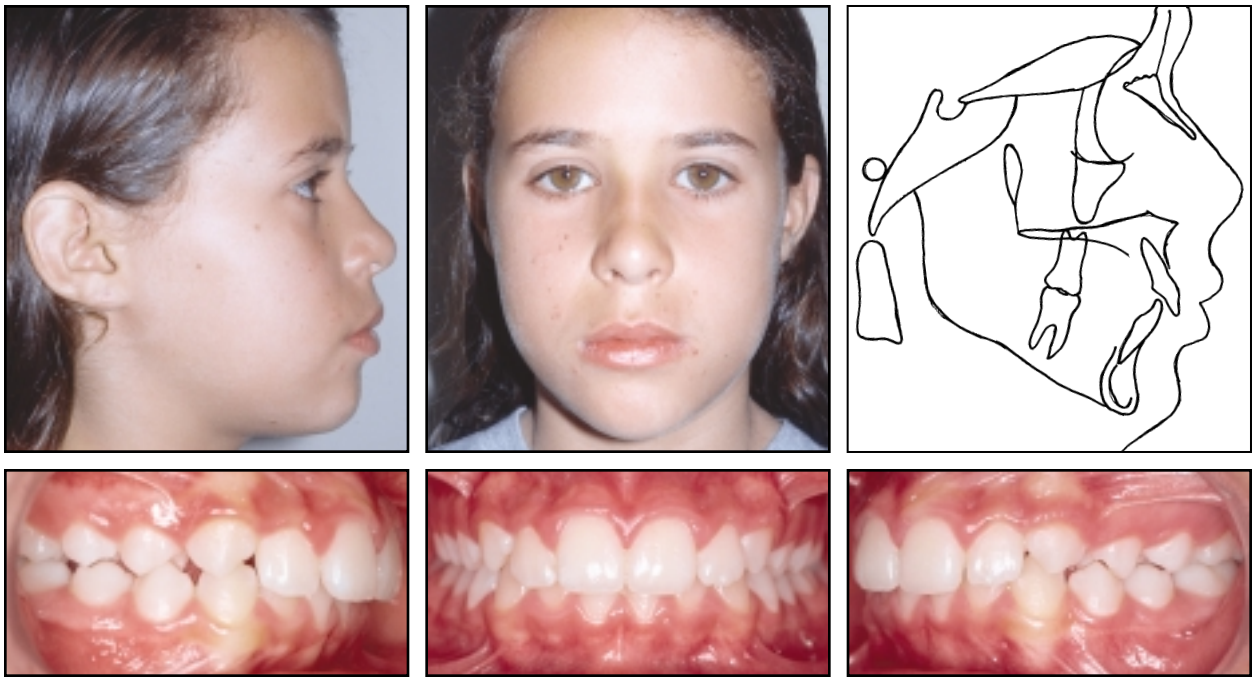

Fig. 10 Case 2. 11-year-old female patient with borderline malocclusion before treatment.

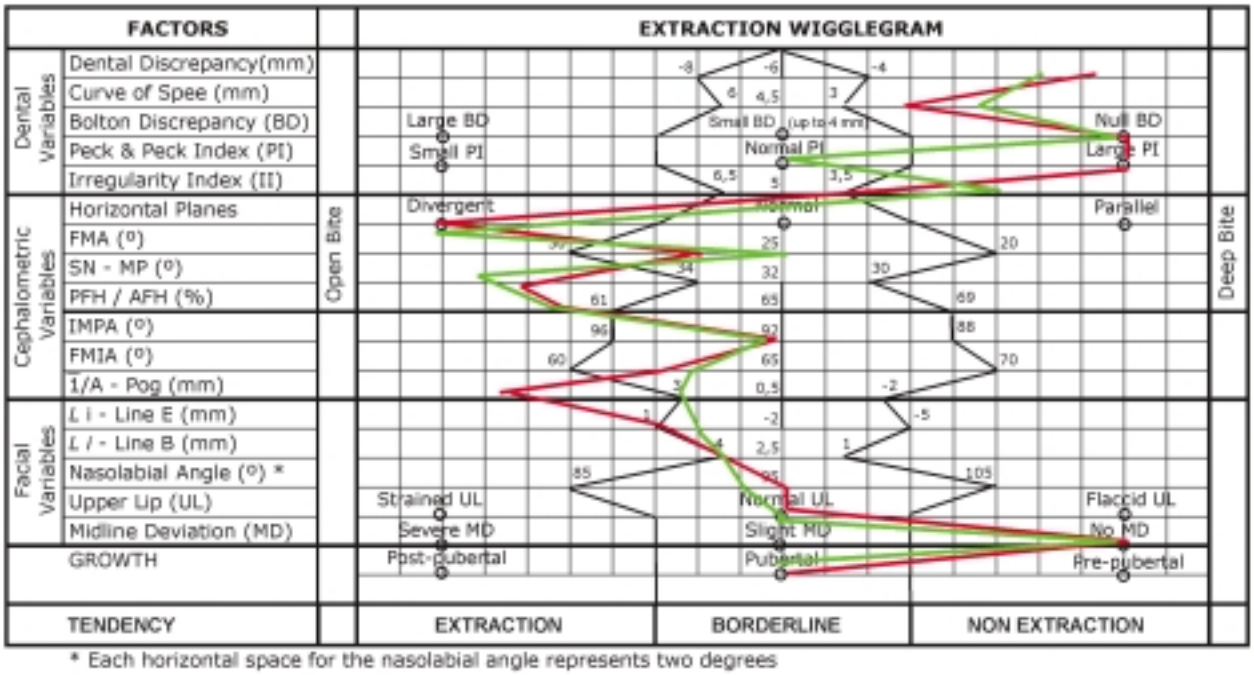

Fig. 11 Case 2. Extraction decision-making wigglegram (red = before treatment; green = after treatment).

tion treatment would have been more necessary.

Conclusion

Certainly, the wigglegram proposed in this article cannot be the only basis for making a decision as complex as whether to extract permanent teeth in orthodontic treatment. It does, however, provide a valuable diagnostic tool in borderline cases. The wigglegram can also be used as a teaching resource to help orthodontic residents visualize patients' extraction requirements.

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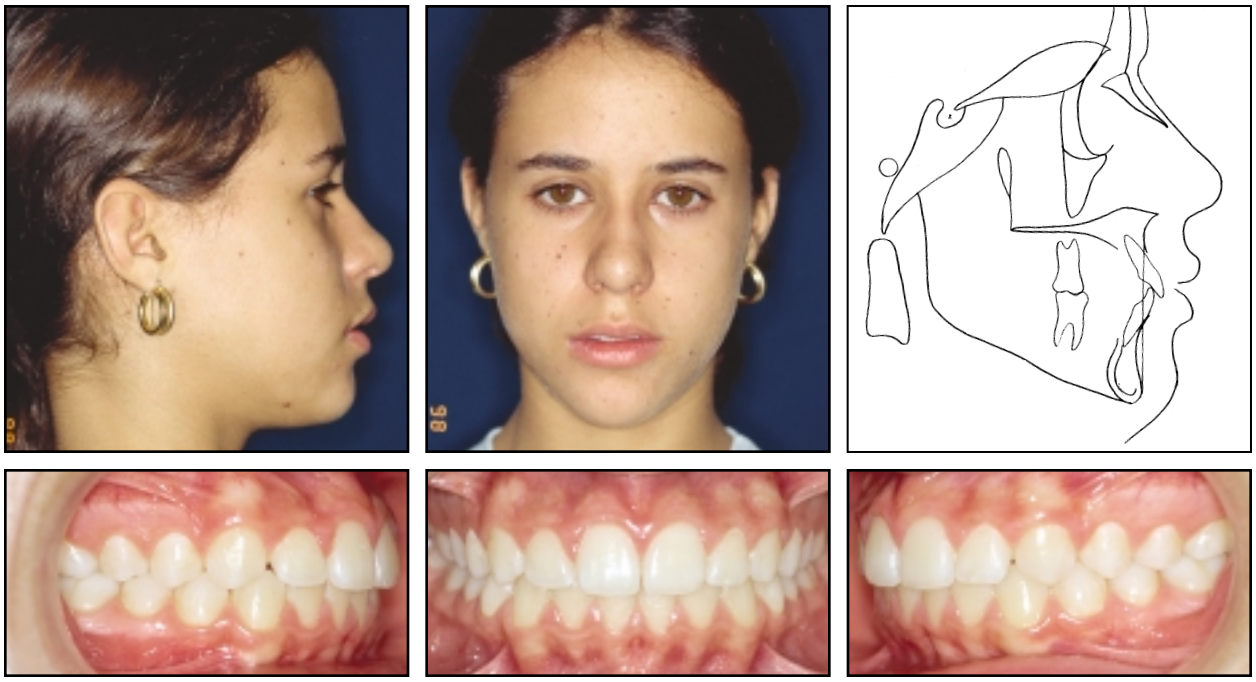

Fig. 12 Case 2. After 30 months of nonextraction treatment.

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