Review Article

Extraction vs. Nonextraction on Soft-Tissue Profile Change in Patients with Malocclusion: A Systematic Review and Meta-Analysis

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Objectives. We aimed to summarize the current evidence regarding the impact of extraction vs. nonextraction in orthodontic treatment on patients’ soft-tissue profile with malocclusion.

Methods. Between April 30th and November 30th, 2020, we searched PubMed and SCOPUS for published papers from inception to November 2020 using “orthodontic,” “extraction,” “nonextraction,” and “Malocclusion.” Included studies were summarized, and relevant data were extracted and analyzed using Review Manager 5.4.

Results. Pooled data from four controlled trials demonstrated a nonsignificant difference between extraction and nonextraction in terms of SNA (MD = 0.50, 95% CI: -0.37, 1.38; p = 0.26), SNB (MD = 0.11, 95% CI: -1.23, 1.44; p = 0.88), FMA (MD = 1.82, 95% CI: -2.39, 6.02; p = 0.40), IMPA (MD = 0.06, 95% CI: -8.83, -8.94; p = 0.99), overjet (MD = -1.47, 95% CI: -6.21, 3.26; p = 0.54), and overbite (MD = 0.50, 95% CI: -1.40, 2.40; p = 0.60). On the other hand, the extraction method significantly increased the ANB compared with the nonextraction group (MD = 0.78, 95% CI: 0.25, 1.31; p = 0.004).

Conclusion. The current evidence demonstrated that nonextraction protocols for orthodontic treatment are a safe and effective alternative to extraction protocols; individually tailored treatment strategies should be applied. More randomized controlled trials are critically needed to safely make an evidence-based treatment conclusion.

1. Introduction

Malocclusion seems to be a frequent dental anomaly that typically develops during childhood as a dental malalignment or inappropriate relationship with the dental arches [1]. Many problems can result from malocclusion including lack of satisfaction with facial appearance, mastication problems, temporomandibular joint dysfunction, swallowing and speech problems, and dental caries development [2].

The patient profile and aesthetics may be affected by orthodontic treatment. Premolar extractions have been suggested to lead to an undesirable flattened facial appearance more than nonextraction treatment [3–5]. While this has been contested in multiple studies [6–9], controversy is still present regarding the role of premolar extraction treatment on soft-tissue changes in class II malocclusion treatment [4, 10].

Many factors influence the decision to choose between the extraction and nonextraction treatments. For example, clinicians with more orthodontic experience tend to choose the extraction option [11]. Extraction treatment is also preferred in cases with class II malocclusion, open-bite problems, and moderate to severe crowding [12]. It is important to consider that extraction treatment is associated with varying degrees of impact on various vertical dimension outcomes, treatment stability, arch widths, perioral soft
tissues, and, subsequently, facial profile [13, 14]. Conversely, nonextraction treatment is generally reserved for minor skeletal and moderate dental discrepancies and crowding.

Multiple previous systematic reviews have tried to address this controversy by combining comparative studies of extraction vs. nonextraction effect on mainly cephalometric perioral soft-tissue changes and facial profile [15–18]. Two of these did not perform quantitative synthesis [15, 16]. Simultaneously, the other two either included mostly potentially biased nonrandomized trials with considerable unresolved heterogeneity [17] or had significant flaws in methodology and a very low number of included studies [18].

Admittedly, the literature’s available evidence is hard to combine and analyze quantitatively since most comparative studies are nonrandomized studies. This is understandable since randomized clinical trials (RCTs)—considered the epitome of clinical research—in orthodontics present serious ethical challenges and have received much criticism [19].

In a metaepidemiologic study, orthodontic intervention outcomes seem to be overstated in non-RCTs compared with RCTs and in retrospective studies compared to prospective studies [20]. This evidence suggests that the nature of the clinical intervention trials may affect estimated treatment effects and that the previous meta-analysis findings on this topic are highly questionable.

In this review, we aim to avoid as much as possible the pitfalls of previous meta-analyses by including only prospective controlled trials reporting on the effect of orthodontic extraction vs. nonextraction on cephalometric outcomes of the facial profile.

2. Methods

During the preparation of this review, the Cochrane Handbook guidelines of Systematic Reviews and Meta-analysis and the Preferred Reporting Items of Systematic Reviews and Meta-Analysis (PRISMA) were followed [21, 22].

2.1. Eligibility Criteria. We included the studies that met our eligibility criteria: (1) studies including patients who were treated either by extraction or nonextraction methods, (2) studies that report data about the dental and soft-tissue changes in response to the treatment, and (3) studies that were experimental in design (RCT, CT, or quasiexperimental). We excluded case reports, animal studies, conference abstracts, and non-English language reviews.

2.2. Information Source and Literature Search. Between April 30th and November 30th, 2020, we searched PubMed and SCOPUS for published papers from inception to November 2020 using these keywords: “orthodontic,” “extraction,” “non-extraction,” and “Malocclusion.”

2.3. Study Selection. The screening process was performed in two steps: (1) title and abstract screening and (2) full-text screening. Both steps were conducted using an offline 2016 Microsoft Excel sheet by two independent reviewers (XX and XX), who assessed the retrieved articles’ eligibility. Any disagreement between both reviewers was resolved by a third reviewer (XX).

2.4. Extraction of the Relevant Data. We extracted the following domains using an offline data extraction sheet [23]: (1) last name of first author, (2) year of publication, (3) design, (4) population characteristics, (5) sample size, (6) accessible data of studied outcomes, and (7) risk of bias.

2.5. Risk of Bias. As described in the Cochrane Handbook for Systematic Reviews of Interventions, we assessed the risk of bias using the Cochrane risk of bias tool (ROB) [24]. Seven domains were evaluated during this step: (1) selection bias, (2) performance bias, (3) detection bias, (4) attrition bias, (5) reporting bias, and (7) other potential sources of bias. The final judgment of the authors was categorized as low, unclear, or high risk of bias.

2.6. Assessment of Heterogeneity. To assess the heterogeneity, we used two methods: (1) visual inspection of the forest plots and (2) using the I²-square (I²) and chi-square (chi²) tests. According to the Cochrane handbook, the interpretation of the I² test should be based on the following cutoff points: minimal (0% to 30%), moderate (30% to 60%), and high (60% to 100%).

2.7. Data Analysis. We used the Review Manager 5.4 software (Windows version) to analyze the mean difference (MD) and its standard deviation (SD) between the extraction and nonextraction groups. The DerSimonian–Laird fixed-and-random-effect models were applied. We conducted the analysis of homogeneous data under the fixed-effect model, while heterogeneous data were analyzed under the random-effect model. We analyzed the available data regarding the following outcomes: SNA, SNB, ANB, FAM, IMPA, overjet, overbite, nasolabial angle, Ls-E-plane, and Li-E-plane. Table 1 presents the reference of each outcome. The sequential algorithm was used to perform the sensitivity analysis.

3. Results

3.1. Literature Searching. We have identified 261 documents through the literature search. As results, five studies were included in the systematic review and meta-analysis with a total of 140 participants (70 extracted, 70 nonextracted, and 20 surgical). Figure 1 shows the screening, inclusion, and exclusion processes.

3.2. Characteristics and Baseline Summary. Two studies were randomized controlled trials, one quasiexperimental and one nonrandomized controlled trial. The mean age of the included participants ranged between 14 and 25.7 years. The majority of included patients were female (75.7%). Regarding the class of malocclusion, class I was reported in two studies: Germeç 2008 (100%) and Khan 2010 (70.5%), while three studies included patients with class II/1: Hemmatpour 2016 (100%), Khan 2010 (29.5%), and Kinzinger 2009 (100%). Two studies extracted four premolars, one study extracted maxillary premolars, and one study extracted one
Table 1: Reference of studied outcomes.

| Outcome         | Index                                                                 |
|-----------------|----------------------------------------------------------------------|
| SNA             | The angle between the anterior cranial base and the deepest concavity of the maxilla’s anterior contour |
| SNB             | The angle between the anterior cranial base and the deepest concavity of the mandible’s anterior contour |
| N               | Most anterior point of the fronthonasal suture in the midsagittal plane |
| A               | The most posterior point in the concavity between the anterior nasal spine and the dental alveolus |
| B               | The most posterior point in the concavity along the anterior border of the symphysis |
| ANB             | The angle formed by NA and NB |
| FMA             | The angle formed by Frankfort horizontal plane and mandibular plane |
| IMPA            | The angle formed by the axial inclination of the mandibular incisor and the mandibular plane |
| Overjet         | Distance between U1i (tip of the maxillary central incisor) and L1i (tip of the mandibular central incisor) in the horizontal plane |
| Overbite        | Distance between U1i (tip of the maxillary central incisor) and L1i (tip of the mandibular central incisor) in the vertical plane |
| Nasolabial angle | The angle formed by columella tangent and Sn- (point at the junction of the columella and upper lip) Ls (most anterior point on the curve of the upper lip) line |
| Ls-E-plane      | Distance from upper lip to the E-line |
| Li-E-plane      | Distance from lower lip to the E-line |
| N’-Pn-Pog’      | The angle formed by soft-tissue nasion, nose tip, and soft-tissue pogonion |
| N’-Sn-Pog’      | The angle formed by soft-tissue nasion, subnasale, and Pog’ |
| Pog’-Sn on FH   | The linear distance between the Pog’ and the subnasale as projected onto the Frankfort horizontal |
| Me’-FH          | The vertical distance between soft-tissue menton and FH |
| Sn-FH           | The vertical distance between subnasale and FH |
| Ls-FH           | The vertical distance between the upper lip and FH |
| Li-FH           | The vertical distance between the lower lip and FH |
| Ls-ML           | Vertical distance between Ls and mandibular line |
| Li-ML           | The vertical distance between Li and mandibular line |
| Sn-ML           | The vertical distance between subnasale and mandibular line |
| Pog’-Pog’       | Chin thickness |
| N’NsPog’        | The angle formed by soft-tissue nasion and Pog’ |
| Ls-PTV          | Distance between the pterygoid vertical plane and Ls |
| Li-PTV          | Distance between the pterygoid vertical plane and li |
| Ls-SnPog’       | The distance formed by upper lip, subnasale, and Pog’ |

Premolars in each quadrant of the upper arch. Table 2 shows a summary of the included studies. Figure 2 summarizes the risk of bias of included studies.

3.3. SNA. Pooled data of three studies showed nonsignificant difference between the extraction and nonextraction groups in terms of SNA (MD = 0.50, 95% CI: -0.37, 1.38; p = 0.26). Pooled data were homogenous ($I^2 = 36\%$; $p = 0.21$), Figure 3(a).

3.4. SNB. Overall effect estimate of three studies showed that there was no significant difference between both extraction and nonextraction groups regarding the SNB (MD = 0.11, 95% CI: -1.23, 1.44; p = 0.88). Pooled data were heterogeneous ($I^2 = 69\%; p = 0.04$). Heterogeneity can be solved by excluding Kinzinger 2008 ($I^2 = 0\%; p = 0.67$). After solving the heterogeneity, the overall effect estimate remained nonsignificant (MD = -0.45, 95% CI: -1.09, 0.19; p = 0.17) (Figure 3(b)).

3.5. ANB. Overall fixed-effect estimate demonstrated that the extraction method significantly increased the ANB compared with the nonextraction group (MD = 0.78, 95% CI: 0.25, 1.31; p = 0.004). Pooled data were homogenous ($I^2 = 38\%; p = 0.20$), Figure 3(c).

3.6. FMA. Pooled data of two studies showed nonsignificant difference between the extraction and nonextraction groups in terms of FMA (MD = 1.82, 95% CI: -2.39, 6.02; p = 0.40). Pooled data were heterogeneous ($I^2 = 79\%; p = 0.03$); however, sensitivity analysis was not applicable, Figure 4(a).

3.7. IMPA. Overall random-effect estimate demonstrated that both extraction and nonextraction methods were
comparable in terms of IMPA (MD = 0.06, 95% CI: -8.83, -8.94; p = 0.99). Pooled data were heterogeneous ($I^2 = 96\%; \ p < 0.00001$). Heterogeneity was best resolved by removing Germeç 2008 and Kinzinger 2008 from the analysis ($I^2 = 60\%; \ p = 0.11$). The overall effect estimate remained nonsignificant (MD = −2.04, 95% CI: -7.42, 3.34; p = 0.46), Figure 4(b).

3.8. Overjet. Pooled data of two studies showed nonsignificant differences between both groups in terms of overjet (MD = −1.47, 95% CI: -6.21, 3.26; p = 0.54). Pooled data were heterogeneous ($I^2 = 97\%; \ p < 0.00001$). Heterogeneity cannot be resolved by sensitivity analysis (Figure 4(c)).

3.9. Overbite. Our analysis demonstrated a nonsignificant difference between both groups in terms of overbite (MD = 0.50, 95% CI: -1.40, 2.40; p = 0.60). Pooled data were heterogeneous ($I^2 = 85\%; \ p = 0.001$). Heterogeneity can be resolved by excluding Kinzinger 2008 from the analysis ($I^2 = 0\%; \ p = 0.57$). After the sensitivity analysis application, the overall effect estimate showed that the extraction method significantly increased the overbite (MD = 1.36, 95% CI: 0.46, 2.25; p = 0.003), Figure 4(d).

3.10. Nasolabial Angle. Overall random-effect estimate demonstrated that both extraction and nonextraction methods were comparable in terms of nasolabial angle (MD = 1.41, 95% CI: -3.61, 6.44; p = 0.58). Pooled data were heterogeneous ($I^2 = 73\%; \ p = 0.01$). Heterogeneity was best resolved by removing Kinzinger 2008 from the analysis ($I^2 = 48\%; \ p = 0.15$). The overall effect estimate remained nonsignificant (MD = 3.78, 95% CI: -0.68, 8.24; p = 0.10) (Figure 5(a)).

3.11. Ls-E-Plane. Pooled data of three studies showed nonsignificant difference between both groups in terms of Ls-E-plane (MD = 0.50, 95% CI: -1.76, 2.75; p = 0.67). Pooled data were heterogeneous ($I^2 = 80\%; \ p = 0.006$). Heterogeneity can be resolved by excluding Khan 2010 from the analysis ($I^2 = 45\%; \ p = 0.18$); however, the overall effect estimate remained nonsignificant (MD = −0.69, 95% CI: -1.96, 0.57; p = 0.28) (Figure 5(b)).

3.12. Li-E-Plane. Pooled data of three studies showed nonsignificant difference between both groups in terms of Li-E-plane (MD = 0.28, 95% CI: -3.18, 3.73; p = 0.88). Pooled data were heterogeneous ($I^2 = 98\%; \ p < 0.00001$). Heterogeneity can be resolved by excluding Khan 2010 from
| Study ID  | Study design | Groups                          | Included patients                                                                 | Female (n) | Age (mean ± SD) | Class I angles | Class II/III angles | Extracted tissue | Studied outcomes | Conclusion                                                                 |
|----------|--------------|--------------------------------|----------------------------------------------------------------------------------|------------|-----------------|-------------------|---------------------|-----------------|-----------------|-----------------------------------------------------------------------------|
| Germeç 2008 | RCT         | Extraction (n = 13)           | Patients with moderate dental arch crowding and balanced facial profiles and dentoskeletal relationships | 11         | 18.1 ± 3.7      | 26 (100%)        | 0                   | Four premolars     | Skeletal, dental, and soft tissue | Both extraction and nonextraction provide comparable outcomes with good facial profile and moderate dental crowding |
|          |              | Nonextraction (n = 13)        |                                                                                  | 11         | 17.8 ± 2.4      |                   |                     |                 |                 |                                                                             |
| Hemmatpour 2016 | RCT       | Extraction (n = 20)           | Patients with 12–18 years old, having permanent dentition only, being at stages 4–6 of cervical vertebral maturation index (CVMI S4–6), having a molar full-cusp class II relationship, having ANB angles C 4, upper-incisor-to-NA-line angles above 18, having full-cusp molar class II, and being clinically proper candidates for upper premolar extraction or fixed functional therapy | 12         | 15.40 ± 0.99    |                   |                     | 140 (100%)       | Maxillary premolar | Skeletal, dental, and soft tissue | Extraction reduced the interincisal angle and protruded the lower incisors |
|          |              | Nonextraction (n = 20)        |                                                                                  | 13         | 15.75 ± 1.02    |                   |                     | 40 (100%)        |                 |                                                                             |
| Khan 2010 | Quasiexperimental | Extraction (n = 17)       | Patients having undergone routine orthodontic treatment                          | 13         | 14 years and 6 months | 24 (70.5%)       | 10                   | Four premolars     | Incisal and soft-tissue effects   | Both extraction and nonextraction provide comparable outcomes              |
|          |              | Nonextraction (n = 17)        |                                                                                  | 13         | 14 years and 8 months | 24 (70.5%)       | 10                   | Four premolars     | Incisal and soft-tissue effects   | Both extraction and nonextraction provide comparable outcomes              |
| Kinzinger 2009 | CT         | Extraction (n = 20)           | Young adults presenting a skeletal class II, division 1 malocclusion              | 33         | 18.7 ± 2.4      |                   |                     | One premolar in each quadrant of the upper arch | Skeletal, dental, and soft tissue | Fixed functional appliances are a treatment alternative to extraction therapy but to a lesser extent to orthognathic surgery |
|          |              | Nonextraction (n = 20)        |                                                                                  | 33         | 17.6 ± 2.3      |                   |                     | One premolar in each quadrant of the upper arch | Skeletal, dental, and soft tissue | Fixed functional appliances are a treatment alternative to extraction therapy but to a lesser extent to orthognathic surgery |
|          |              | Surgical group (n = 20)       |                                                                                  | 33         | 25.7 ± 5.4      |                   |                     |                 |                 |                                                                             |

RCT: randomized control trial; SD: standard deviation; CT: clinical trial; n: number.
the analysis ($I^2 = 0$; $p = 0.41$), showing a significant reduction in the Li-E-plane within the extraction group (MD = −1.49, 95% CI: -2.31, -0.66; $p = 0.0004$) (Figure 5(c)).

3.1.3. Results of Individual Studies. Kinzinger and his colleagues [25] reported a nonsignificant ($p = 1.00$) difference between the extraction and nonextraction groups in terms of $N'_{\cdot \cdot} \cdot \cdot -Pn \cdot \cdot -Pog'$ ($−0.75 ± 3.98$ vs. $−0.79 ± 3.28$, respectively) and $N'_{\cdot \cdot} \cdot \cdot -Sn \cdot \cdot -Pog'$ ($−1.04 ± 5.26$ vs. $−1.24 ± 4.22$, respectively). Similarly, their findings showed that the effect of both groups was comparable ($p > 0.05$) in the following outcomes: $Pog' \cdot \cdot \cdot Sn$ on FH, $Me' \cdot \cdot \cdot FH$, $Sn \cdot \cdot \cdot FH$, $Ls \cdot \cdot \cdot FH$, $Li \cdot \cdot \cdot FH$, $Ls \cdot \cdot \cdot ML$, $Li \cdot \cdot \cdot ML$, and $Sn \cdot \cdot \cdot ML$.

![Figure 2: Summary of the risk of bias of included studies.](image)

![Figure 3: (a–c) The heterogeneity and test for overall effect.](image)
In the study of Hemmatpour et al. [26], the authors demonstrated that the nonextraction method significantly increased the N’s-Gn’ ($p = 0.029$), N’sPog’ ($n = 0.002$), Pog-Pog’ ($p = 0.03$), and SS-Ls ($p = 0.001$), compared to the extraction group.

Germeç and Taner [3] reported that there was no significant difference between the extraction and nonextraction groups in terms of Ls and Li thickness ($p = 0.64$ and $p = 0.83$), respectively. Likewise, the superior and inferior sulcus depths were similar in both groups ($p = 0.83$ and $p = 0.22$), respectively. Their findings also showed that both groups reduced the maxillary and mandibular sulcus contour with no significant difference ($p = 0.36$ and $p = 0.41$). On the other hand, the Ls-PTV, Li-PTV, and Ls-SnPog were significantly ($p < 0.05$) reduced in the extraction group compared to the nonextraction group. Similar to these findings, Khan and Fida [27] found that extraction was associated with a significant reduction in the upper and the lower lip procumbency ($p = 0.004$ and $0.021$). However, they showed that there was no significant ($p > 0.05$) difference between both groups in terms of Ls thickness and nasolabial and mentolabial angles.

4. Discussion

In this review, we compiled evidence from clinical trials about cephalometric parameters’ changes following extraction vs. nonextraction protocols in orthodontic fixation treatment of malocclusion. Four studies were included: two randomized clinical trials, one quasiexperimental trial, and one nonrandomized trial.

While the overall evidence from these studies did not show a statistically significant difference between extraction and nonextraction in our defined outcomes, it has demonstrated that nonextraction is a less interventional, safe, and similarly effective alternative to extraction in malocclusion patients [28]. This is evidenced by cephalometric analysis.
parameters (SNA, SNB, FAM, IMPA, overjet, overbite, nasolabial angle, Ls-E-plane, and Li-E-plane), which were similar in extraction and nonextraction. It is necessary to keep in mind that the treatment’s overall facial attractiveness is more important than final cephalometric values [29]. Accordingly, this consideration was in agreement with our results since multiple studies demonstrated that extraction was not superior to nonextraction in terms of long-term facial aesthetics, age appearance, and soft-tissue measures [30–32].

Our results were also in agreement with Zierhut et al., who demonstrated that the facial profiles of patients with class II division 1 malocclusion who were successfully treated with extraction and nonextraction treatments were similar [33]. The authors also concluded that the facial profile flattening during treatment and long-term follow-up was primarily due to maturational changes and was not influenced by whether teeth were removed [33].

Extraction treatment is associated with multiple adverse effects, which it may share with nonextraction treatment with various degrees of difference. Extraction is associated with less support for the upper lip after extraction with a flattened, less attractive facial profile [34]. Also, extraction leaves less space for the tongue as the arches become smaller, forcing the tongue to take a backward position, leading to airway blockage and mouth breathing problems [35]. Extraction treatment has also been associated with a higher risk for sleep apnea with its many complications due to restricted space [36]; however, this has been contested [37]. More significantly, extraction has been variably linked to chronic pain and functional bite issues resulting from retrusion [38–41].

In a study of 16 orthodontic female patients treated with extraction of premolars, the authors reported that about 12 percent of their sample finished their treatment with a more retrusive facial profile, and if a strict interpretation of numbers had been applied, this percentage would rise to 62% [42]. Furthermore, extraction protocols have been associated with narrower airway size. Recent studies have pointed out that extraction affected the velopharyngeal, glossopharyngeal, hypopharyngeal, and hyoid position and that the velopharyngeal, glossopharyngeal, and hypopharyngeal airway became narrower following orthodontic therapy [43, 44]. Although extraction treatment has been suggested to help with facial height reduction, some studies have contested this. It has been shown that the bicuspid extraction technique for facial height reduction does not provide any statistically significant changes for patients after treatment [45, 46].

A case for extraction treatment could be argued, however, for a special subset of patients. One study showed that extraction treatment commonly produces positive results for patients where the objective is to reduce lip procumbent [47]. Another study showed that premolar extractions
positively influenced the developing maxillary third molar angulations, and these improved angulations could favor third molar eruptions later in life [48]. Combined with the potentially negative aspects of many nonextraction treatment types (such as instability, procumbent, and inefficiency), careful choice of evidence-based treatment decisions should be considered.

Although our study managed to avoid the bias included in previous meta-analyses, which compiled data from retrospective, nonrandomized trials, our study is still limited by the small number of studies included and the subsequently small sample size. The difference between the endpoints of our study and previous meta-analyses makes a comparison of outcomes questionable. As shown previously, both treatment protocols did not differ, and the implications of our results were similar. Although addressed by removing one or more studies during quantitative synthesis, heterogeneity should be considered during clinical decision-making. Moreover, the trial by Kinzinger et al. was nonrandomized and is subject to selection bias.

5. Conclusion

The current evidence demonstrated that the extraction method might be associated with some soft-tissue benefits in case of a convex profile with acute nasolabial angle; however, nonextraction protocols for orthodontic treatment are a safe and effective alternative to extraction protocols; individually tailored treatment strategies should be applied. More randomized controlled trials are critically needed to safely make an evidence-based treatment conclusion.

Abbreviations

| Abbreviation | Description |
|--------------|-------------|
| RCTs: | Randomized control trials |
| SD: | Stander deviation |
| CT: | Clinical trial |
| CI %: | Percentage of the confidence interval |
| n: | Number |
| ROB: | Risk of bias |
| MD: | Mean difference |
| p: | Value of probability |
| SNA: | The angle between the anterior cranial base and the deepest concavity of the maxilla’s anterior contour |
| SNB: | The angle between the anterior cranial base and the deepest concavity of the mandible’s anterior contour |
| N: | Most anterior point of the frontonasal suture in the midsagittal plane |
| A: | The most posterior point in the concavity between the anterior nasal spine and the dental alveolus |
| B: | The most posterior point in the concavity along the anterior border of the symphysis |
| ANB: | The angle formed by NA and NB |
| FMA: | The angle formed by the Frankfort horizontal plane and mandibular plane |
| IMPA: | The angle formed by the axial inclination of the mandibular incisor and the mandibular plane |
| Overjet: | Distance between U1i (tip of the maxillary central incisor) and L1i (tip of the mandibular central incisor) in the horizontal plane |
| Overbite: | Distance between U1i (tip of the maxillary central incisor) and L1i (tip of the mandibular central incisor) in the vertical plane |
| Nasolabial angle: | The angle formed by columella tangent and Sn- (point at the junction of the columella and upper lip) Ls (most anterior point on the curve of the upper lip) line |
| Ls-E-plane: | Distance from upper lip to the E-line |
| Li-E-plane: | Distance from lower lip to the E-line |
| N’-Pn-Pog’ : | The angle formed by soft-tissue nasion, nose tip, and soft-tissue pogonion |
| N’-Sn-Pog’ : | The angle formed by soft-tissue nasion, subnasale, and Pog’ |
| Pog’-Sn on FH: | The linear distance between the Pog’ and the subnasale as projected onto the Frankfort horizontal |
| Me’-FH: | The vertical distance between soft-tissue menton and FH |
| Sn-FH: | The vertical distance between subnasale and FH |
| Ls-FH: | The vertical distance between the upper lip and FH |
| Li-FH: | The vertical distance between the lower lip and FH |
| Ls-ML: | The vertical distance between Ls and mandibular line |
| Li-ML: | The vertical distance between Li and mandibular line |
| Sn-ML: | The vertical distance between subnasale and mandibular line |
| Pog-Pog’ : | Chin thickness |
| N’NsPog : | The angle formed by soft-tissue nasion and Pog’ |
| Ls-PTV: | Distance between the pterygoid vertical plane and Ls |
| Li-PTV: | Distance between the pterygoid vertical plane and Li |
| Ls-SnPog’ : | The distance formed by the upper lip, subnasale, and Pog’. |

Data Availability

Data will be available when requested from the corresponding author.

Conflicts of Interest

The authors declare that they have no competing interests.
Authors’ Contributions

The 1st author was responsible for conceiving and designing the study, collecting data, data analysis, and paper writing; the 2nd author was responsible for collecting data, data analysis, and paper writing; the 3rd author was responsible for paper writing; the 4th author was responsible for collecting data and data analysis; the 5th author was responsible for conceiving and designing the study and collecting data; and the last author (corresponding) was responsible for conceiving and designing the study, collecting data, data analysis, and paper reviewing.

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References

[1] M. Mtaya, P. Brudvik, and A. N. Åström, “Prevalence of malocclusion and its relationship with socio-demographic factors, dental caries, and oral hygiene in 12- to 14-year-old Tanzanian schoolchildren,” European Journal of Orthodontics, vol. 31, no. 5, pp. 467–476, 2009.

[2] W. R. Proffit, H. W. Fields, and D. M. Sarver, Contemporary Orthodontics, Mosby Elsevier, St. Louis, Mo, 2007.

[3] D. Germeç and T. U. Taner, “Effects of extraction and nonextraction therapy with air-rotor stripping on facial esthetics in postadolescent borderline patients,” American Journal of Orthodontics and Dentofacial Orthopedics, vol. 133, no. 4, pp. 539–549, 2008.

[4] C. Weyrich and J. A. Lisson, “Auswirkungen von prämolarextaktionen auf schneidezahnstellung und profil bei patienten mit angle-klasse II,1,” Journal of Orofacial Orthopedics, vol. 70, no. 2, pp. 128–138, 2009.

[5] H. J. Lim, K. T. Ko, and H. S. Hwang, “Esthetic impact of premolar extraction and nonextraction treatments on Korean borderline patients,” American Journal of Orthodontics and Dentofacial Orthopedics, vol. 133, no. 4, pp. 524–531, 2008.

[6] S. E. Bishara and J. R. Jakobsen, “Profile changes in patients treated with and without extractions: assessments by lay people,” American journal of orthodontics and dentofacial orthopedics, vol. 112, no. 6, pp. 639–644, 1997.

[7] Y. Stromboni, “Facial aesthetics in orthodontic treatment with and without extractions,” The European Journal of Orthodontics, vol. 1, no. 3, pp. 201–206, 1979.

[8] O. B. Drobockey and R. J. Smith, “Changes in facial profile during orthodontic treatment with extraction of four first premolars,” American Journal of Orthodontics and Dentofacial Orthopedics, vol. 95, no. 3, pp. 220–230, 1989.

[9] R. D. James, “A comparative study of facial profiles in extraction and nonextraction treatment,” American journal of orthodontics and dentofacial orthopedics, vol. 114, no. 3, pp. 265–276, 1998.

[10] A. Hodges, P. E. Rossouw, P. M. Campbell, J. C. Boley, R. A. Alexander, and P. H. Buschang, “Prediction of lip response to four first premolar extractions in white female adolescents and adults,” Angle Orthodontist, vol. 79, no. 3, pp. 413–421, 2009.

[11] N. Saghaﬁ, L. J. Heaton, B. Bayirli, D. L. Turpin, R. Khosravi, and A. M. Bollen, “Influence of clinicians’ experience and gender on extraction decision in orthodontics,” Angle Orthodontist, vol. 87, no. 5, pp. 641–650, 2017.

[12] T. H. Jackson, C. Guez, F. C. Lin, W. R. Proffit, and C. C. Ko, “Extraction frequencies at a university orthodontic clinic in the 21st century: demographic and diagnostic factors affecting the likelihood of extraction,” American Journal of Orthodontics and Dentofacial Orthopedics, vol. 151, no. 3, pp. 456–462, 2017.

[13] C. Kirschneck, P. Proff, C. Reicheneder, and C. Lippold, “Short-term effects of systematic premolar extraction on lip profile, vertical dimension and cephalometric parameters in borderline patients for extraction therapy—a retrospective cohort study,” Clinical Oral Investigations, vol. 20, no. 4, pp. 865–874, 2016.

[14] C. Herzog, D. Konstantonis, N. Konstantoni, and T. Eliades, “Arch-width changes in extraction vs nonextraction treatments in matched class I borderline malocclusions,” American Journal of Orthodontics and Dentofacial Orthopedics, vol. 151, no. 4, pp. 735–743, 2017.

[15] R. Leonard, A. Annunziata, V. Liciardiello, and E. Barbato, “Soft tissue changes following the extraction of premolars in nongrowing patients with bimaxillary protrusion,” Angle Orthodontist, vol. 80, no. 1, pp. 211–216, 2010.

[16] G. Janson, L. M. Mendes, C. H. Z. Junqueira, and D. G. Garib, “Soft tissue changes in class II malocclusion patients treated with extractions: a systematic review,” European Journal of Orthodontics, vol. 38, no. 6, pp. 631–637, 2016.

[17] D. Konstantonis, D. Vasileiou, S. N. Papageorgiou, and T. Eliades, “Soft tissue changes following extraction vs. nonextraction orthodontic fixed appliance treatment: a systematic review and meta-analysis,” European Journal of Oral Sciences, vol. 126, no. 3, pp. 167–179, 2018.

[18] W. Iared, E. M. Koga da Silva, W. Iared, and C. Rufino Macedo, “Esthetic perception of changes in facial profile resulting from orthodontic treatment with extraction of premolars: a systematic review,” Journal of the American Dental Association, vol. 148, no. 1, pp. 9–16, 2017.

[19] G. Zuccati, C. Clauser, and R. Giorgetti, “Randomized clinical trials in orthodontics: reality, dream, or nightmare?,” American Journal of Orthodontics and Dentofacial Orthopedics, vol. 136, no. 5, pp. 634–637, 2009.

[20] S. N. Papageorgiou, G. M. Xavier, and M. T. Cobourne, “Basic study design influences the results of orthodontic clinical investigations,” Journal of Clinical Epidemiology, vol. 68, no. 12, pp. 1512–1522, 2015.

[21] A. Liberati, D. G. Altman, J. Tetzlaff et al., “The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration,” Bmj, vol. 339, no. jul21 1, p. b2700, 2009.

[22] J. P. T. Higgins, J. Thomas, J. Chandler et al., Cochrane Handbook for Systematic Reviews of Interventions. 2nd edition, John Wiley & Sons, Chichester (UK), 2019.

[23] M. Efﬁ, E. I. Bahbah, M. M. Attia, M. Eldokmak, and B. B. Koo, “Impact of obstructive sleep apnea on cognitive and motor functions in Parkinson’s disease,” Movement Disorders, vol. 36, no. 3, pp. 570–580, 2021.
C. J. Wholley and M. G. Woods, “The Cochrane Collaboration’s tool for assessing risk of bias in randomised trials,” *BMJ*, vol. 343, no. oct18 2, 2011.

G. Kinzinger, L. Frye, and P. Diedrich, “Distalisationbehandlung bei adulten: camouflage-orthodontie versus dentofaziale orthopädie versus dysgnathiechirurgie. Eine kephalometrische studie zur evaluierung differentialtherapeutischer effekte,” *Journal of Orofacial Orthopedics*, vol. 70, no. 1, pp. 63–91, 2009.

S. Hemmatpour, A. Mokhtar, and V. Rakshan, “Effects of Sabbagh Universal Spring 2 fixed functional appliance on class II/1 patients at their postpubertal-peak growth period compared with the extraction method,” *Journal of Orofacial Orthopedics*, vol. 78, no. 1, pp. 41–51, 2017.

M. Khan and M. Fida, “Soft tissue profile response in extraction versus non-extraction orthodontic treatment,” *Journal of the College of Physicians and Surgeons Pakistan*, vol. 20, no. 7, pp. 454–459, 2010.

V. Grassia, L. Nucci, P. M. Marra, G. Isola, A. Itro, and L. Perillo, “Long-term outcomes of nonextraction treatment in a patient with severe mandibular crowding,” *Case Reports in Dentistry*, vol. 2020, Article ID 1376472, 7 pages, 2020.

L. Nucci, P. M. Marra, L. Femiano et al., “Perioral muscle activity changes after lip bumper treatment,” *European Journal of Paediatric Dentistry*, vol. 22, no. 2, pp. 129–134, 2021.

J. C. Boley, J. P. Pontier, S. Smith, and M. Fulbright, “Facial changes in extraction and nonextraction patients,” *Angle Orthodontist*, vol. 68, no. 6, pp. 539–546, 1998.

C. K. Stephens, J. C. Boley, R. G. Behrents, R. G. Alexander, and P. H. Buschang, “Long-term profile changes in extraction and nonextraction patients,” *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 128, no. 4, pp. 450–457, 2005.

G. Janson, C. H. Z. Junqueira, L. M. Mendes, and D. G. Garib, “Influence of premolar extractions on long-term adult facial aesthetics and apparent age,” *European Journal of Orthodontics*, vol. 38, no. 3, pp. 272–280, 2016.

E. C. Zierhut, D. R. Joondeph, J. Artun, and R. M. Little, “Long-term profile changes associated with successfully treated extraction and nonextraction class II division 1 malocclusions,” *Angle Orthodontist*, vol. 70, no. 3, pp. 208–219, 2000.

C. J. Wholley and M. G. Woods, “The effects of commonly prescribed premolar extraction sequences on the curvature of the upper and lower lips,” *Angle Orthodontist*, vol. 73, no. 4, pp. 386–395, 2003.

Z. Hu, X. Yin, J. Liao, C. Zhou, Z. Yang, and S. Zhou, “The effect of teeth extraction for orthodontic treatment on the upper airway: a systematic review,” *Sleep and Breathing*, vol. 19, no. 2, pp. 441–451, 2015.

J. H. Ng, Y. L. Song, and A. U. J. Yap, “Effects of bicuspid extractions and incisor retraction on upper airway of Asian adults and late adolescents: a systematic review,” *Journal of Oral Rehabilitation*, vol. 46, no. 11, pp. 1071–1087, 2019.

A. J. Larsen, D. B. Rindal, J. P. Hatch et al., “Evidence supports no relationship between obstructive sleep apnea and premolar extraction: an electronic health records review,” *Journal of Clinical Sleep Medicine*, vol. 11, no. 12, pp. 1443–1448, 2015.

A. Conti, M. Freitas, P. Conti, J. Henriques, and G. Janson, “Relationship between signs and symptoms of temporomandibular disorders and orthodontic treatment: a cross-sectional study,” *Angle Orthodontist*, vol. 73, no. 4, pp. 411–417, 2003.

S. Legris and S. Legris, “Managing pain and discomfort in orthodontics,” *Journal of Dental Facial Anomalies and Orthodontics*, vol. 14, no. 1, p. 109, 2011.

N. F. Talic, “Adverse effects of orthodontic treatment: a clinical perspective,” *Saudi Dental Journal*, vol. 23, no. 2, pp. 55–59, 2011.

C. Barbosa, S. Gavinta, T. Soares, and M. Manso, “Coincidence and awareness of the relationship between temporomandibular disorders and jaw injury, orthodontic treatment, and third molar removal in university students,” *Journal of Oral & Facial Pain and Headache*, vol. 30, no. 3, pp. 221–227, 2016.

L. A. Bravo, “Soft tissue facial profile changes after orthodontic treatment with four premolars extracted,” *Angle Orthodontist*, vol. 64, no. 1, pp. 31–42, 1994.

Q. Wang, P. Jia, N. K. Anderson, L. Wang, and J. Lin, “Changes of pharyngeal airway size and hyoid bone position following orthodontic treatment of class i bimaxillary protrusion,” *Angle Orthodontist*, vol. 82, no. 1, pp. 115–121, 2012.

K. Sharma, S. Shrivastav, N. Sharma, K. Hotwani, and M. D. Murrell, “Effects of first premolar extraction on airway dimensions in young adolescents: a retrospective cephalometric appraisal,” *Contemporary Clinical Dentistry*, vol. 5, no. 2, pp. 190–194, 2014.

A.-H. Zafarmand and M.-M. Zafarmand, “Premolar extraction in orthodontics: does it have any effect on patient’s facial height?”, *Journal of International Society of Preventive and Community Dentistry*, vol. 5, no. 1, pp. 64–68, 2015.

J. A. Staggers, “Vertical changes following first premolar extractions,” *American Journal of Orthodontics and Dentofacial Orthopedics*, vol. 105, no. 1, pp. 19–24, 1994.

S. J. Bowman and L. E. Johnston, “The esthetic impact of extraction and nonextraction treatments on Caucasian patients,” *Angle Orthodontist*, vol. 70, no. 1, pp. 3–10, 2000.

A. Gohilot, T. Pradhan, and K. M. Keluskar, “Effects of first premolar extraction on maxillary and mandibular third molar angulation after orthodontic therapy,” *Journal of Oral Biology and Craniofacial Research*, vol. 2, no. 2, pp. 97–104, 2012.