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Evaluation of the diagnostic ability of the Fränkel manoeuvre to detect the contributing jaw in angle class II division 1 malocclusion

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Abstract

Background A correct diagnosis of patients with an Angle Class II malocclusion is needed to guide treatment decisions toward the contributing jaw and to achieve better treatment outcomes. The aim of the study is to evaluate the diagnostic potential of the Fränkel manoeuvre (FM) for detecting the components determining sagittal discrepancy in Angle Class II division 1.

Materials and methods Anonymous questionnaires containing photographs were distributed totwo groups: general practitioner (GP) dentists and orthodontists. The level of the patient's profile aesthetics before (T0) and after (T1) the manoeuvre was determined using a 100 mm visual analog scale, and the 'profile improvement' score was defined as T1 minus T0. The diagnostic ability of the FM was calculated by comparison with lateral cephalometry as a reference standard using receiver operating characteristic (ROC) curve analysis.

Results A total of 102 respondents participated in the survey; 40 were orthodontists, and 62 were GP dentists. According to the post-FM images, the "profile improvement" score (T1-T0) was significantly greater in patients with mandibular retrusion than in those with maxillary protrusion ($p < 0.05$). The predictive power of FM, coinciding with the area under the ROC curve, was 0.62 for GPs and 0.78 for orthodontists.

Conclusions The FM method is a useful and accurate tool for diagnosing skeletal Angle Class II malocclusion etiology (mandibular retrusion or maxillary protrusion), especially when used by orthodontists.

Keywords Fränkel manoeuvre, Angle Class II, Diagnosis, Mandibular retrusion, Maxillary protrusion

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Background

Orthodontic malocclusion is a common problem that significantly impacts the quality of life of affected people. Misaligned teeth and imbalanced jaw growth not only affect facial aesthetics but also hinder oral function. Angle Class II malocclusion is a prevalent skeletal anomaly, and the goal of orthodontic treatment is to achieve optimal facial aesthetics, a harmonious profile, and a functional bite. Research has shown that a small mandibular size or a retrognathic position of the mandible is the primary cause of Class II skeletal occlusion. The prognosis for this condition depends on factors such as the position and size of the upper and lower jaw, as well as their relationship [1].

A correct diagnosis in Class II patients is needed to guide treatment decisions for the causative jaw and achieve better aesthetic results. The diagnostic process for assessing sagittal skeletal discrepancies in growing individuals includes both cephalometric and the Sella-Nasion-A point (SNA) and Sella-Nasion-B point (SNB) angles Steiner analysis is frequently used to represent the sagittal position of the mandible or maxilla in relation to the base of the skull, but the values of these angles are affected by the steepness of the Sella-Nasion (SN) line aesthetic assessments [2].

Cephalometric analysis uses linear and angular measurements to determine the etiology of malocclusion. However, the use of cephalometry is associated with limitations in the decision-making process [3, 4]. The use of linear measurements is associated with individual differences in age, sex, and race [5]. Cephalometric assessments may not always correlate with clinical data and can lead to misleading results when comparing different analyses of the same patient [6]. Furthermore, lateral cephalography is usually not performed during the initial clinical examination, which emphasises the value of clinical readings in identifying the primary skeletal etiology of malocclusion.

Several clinical indicators have been proposed to aid in the diagnosis of Class II malocclusion [7]. For the aesthetic assessment of individuals with mandibular retrognathia, it is valuable to observe the position of the chin. The forward projection of the upper lip may indicate a protruding upper jaw, while the backwards projection of the lower lip may indicate a retrognathic position of the lower jaw. However, the position of the lips is strongly influenced by the position of the front teeth and the inclination [8]. Changing the facial profile of patients with Class II Division 1 by posturing the mandible forward is a useful diagnostic tool and can be aesthetically evaluated during the Fränkel manoeuvre (FM). FM is a clinical procedure in which the mandible of a subject with a Class II malocclusion is moved forward so that the molars and canine teeth can achieve a Class I relationship [9]. This manoeuvre is considered to provide useful information on the manifestations of skeletal Class II discrepancy. Aesthetic facial profile improvement following FM indicates mandibular retrognathia, while profile deterioration, expressed by the protrusive appearance of both jaws, is indicative of maxillary prognathia or a combination of a protrusive maxilla and a retrusive mandible [2].

There are only a few articles that have focused on the FM [2, 9, 10], but the number of studies investigating its diagnostic potential to identify the causative Class II Division 1 of the jaw and its compatibility with cephalometric results is very limited. There is a lack of information in the literature on the accuracy of diagnostic tools used in clinical practice.

The FM could be an adaptable and reliable clinical tool to identify the aetiology of skeletal Class II malocclusion and could predict the outcome of treatment for the facial profile, if the reliability of the manoeuvre would be proven.

The aim of our study was to evaluate the diagnostic potential of the FM for detecting the contributing jaw in Class II Division 1 malocclusion patients.

Methods

Research methods

We employed a quantitative research method by conducting an anonymous questionnaire survey. The questionnaire was used to gather data on patient profile aesthetics. This questionnaire was developed based on the work of Ahrari et al. [9] and focused on the aesthetics of the patient profile. We assessed the level of profile aesthetics before (T0) and after (T1) the manoeuvring using a 100 mm visual analog scale. The "profile improvement" score was defined as T1 minus T0. Additionally, we included supplementary author questions in the questionnaire. The images below (Fig. 1) illustrate the profile before and after the manoeuvre.

The diagnostic potential of the FM was assessed by comparison to that of lateral cephalometry, considered a reference standard.

Study sample

The data for the study were obtained from the Dolphin Imaging 11 database at the Orthodontic Clinic of the Lithuanian University of Health Sciences. The patient group selected for the study had Class II Division 1 malocclusion. The first image was captured with the head in a natural position, while the second image was taken during the FM. The inclusion criterion mandated the presence of an established Class II malocclusion characterised by a "cusp to cusp" relationship of the posterior molars and a horizontal overlap exceeding 6 mm. The exclusion criteria included patients with congenital

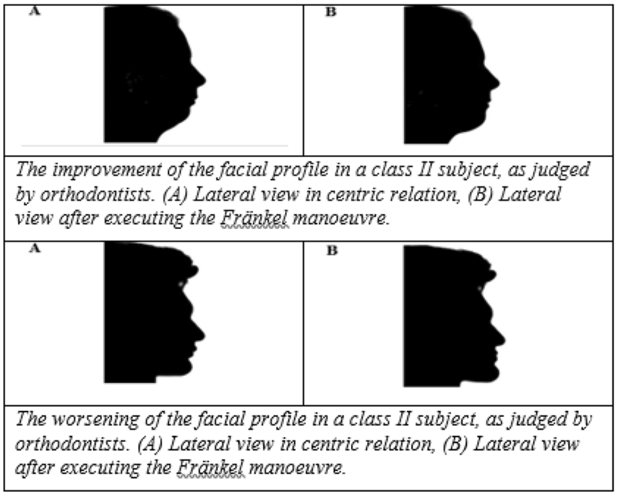

Fig. 1 Facial profile before (T0) and after (T1) the FM

syndromes, previous orthodontic treatment, or asymmetrical facial growth.

Patients' cephalograms were also collected from the system. All cephalograms were evaluated using Dolphin software (Dolphin Imaging System 11.95, Chatsworth, CA). Steiner and McNamara analyses were used to determine the jaw responsible for Class II discrepancies. If the angle between the SN and Frankfort Horizontal (FH) planes fell between 5° and 7°, the SNA and SNB were used to identify the jaw angles. A SNB angle of ≤76°, coupled with an SNA within the normal range (80° ≤ SNA ≤ 82°), indicated a relatively small mandible, whereas an SNA ≥ 83° suggested maxillary protrusion.

In cases where the difference between the SN and FH planes exceeded the 5°-7° range, McNamara analysis was applied [9]. This analysis involved measuring the distance between point A and the N-perpendicular line and the anterior hard tissue chin point (pogonion; Pg) relative to the line perpendicular to N. If the distance between point A and the N-perpendicular line was more than 1 mm, the diagnosis of maxillary protrusion was confirmed; if the Pg was more than 8 mm behind the N-perpendicular line, the mandible was considered to be retrusive.

All patient information was deidentified and used only for statistical and research purposes. In this study, the contributing jaw for Class II Division 1 was identified using cephalometric analysis as a reference standard.

Subjects

The study involved Lithuanian orthodontists and general practitioner (GP) dentists. This study was conducted from October 1, 2022, to January 31, 2023, with prior permission granted by the Bioethics Centre of the Lithuanian University of Health Sciences (Approval No. BEC-OF14, dated 09/09/2022). Subjects were selected through simple random sampling. The inclusion criteria included Lithuanian orthodontists and Lithuanian GP dentists. The exclusion criteria removed Lithuanian dental students and Lithuanian dentists who had completed other residency programs at a medical academy and who possessed an invalid general dentist licence.This ensures that sample is representative of the population of interest, relevant to research objectives, and maintains the integrity and validity of study findings.

Sample size calculation

Paniotto's formula was used to calculate the representative sample size: $n = 1/(\Delta 2 + 1/N)$, where n is the sample size, Δ is the margin of error and N is the population size. Sample representativeness with tolerance with a margin of error not exceeding 5% is ensured by 101 orthodontists and 357 general practitioners The sample shall be representative of the sample of general dentists.

After sample calculation, a sample of at least 10% of the subjects was required to match the pilot study according to Hertzog [11]. The sample in the present study included at least 10 orthodontists and 36 GP dentists.

Statistical analysis

In the quantitative study, the data were combined and coded using Microsoft Excel 2010. Subsequently, statistical analysis was conducted with IBM SPSS version 27.0.

The diagnostic potential of the FM was assessed in comparison to that of lateral cephalometry, which served as the reference standard. Receiver operating characteristic (ROC) curve analysis was also conducted to determine the sensitivity and specificity of the various thresholds for improving the aesthetic profile. The highest cut-off value, which yielded the maximum combined sensitivity and specificity, was considered capable of distinguishing the jaw anomaly responsible for skeletal Angle Class II malocclusion.

The area under the curve (AUC) was calculated to assess the diagnostic potential of the FM as determined by each assessor group.

Statistical significance was determined with a threshold of $p < 0.05$, indicating that the results were considered to be statistically reliable.

Results

Subjects

A total of 102 respondents participated in the survey; 36 (35.3%) were males, and 66 (64.7%) were females. Among these respondents, 40 were orthodontists and 62 were GP dentists. The mean age of the subjects was 36.71 years (with a standard deviation (SD) of 11.25). The participants in this study had an average of 9.92 years of work experience (with a SD of 10.375).

Table 1 Mean and SD improvement scores after FM in patients with class II malocclusion of different aetiologies according to assessment by GPs

Group	Mean	SD
Mandibular retrusion	21.4	16.8
Maxillary protrusion	13.5	19.1
Statistical Significance	$P=0.0159$	

Table 2 Mean and SD of improvement scores after FM in patients with class II malocclusion of different aetiologies according to orthodontist evaluation

Group	Mean	SD
Mandibular retrusion	29.4	22.3
Maxillary protrusion	5.0	23.2
Statistical Significance	$P<0.0001$	

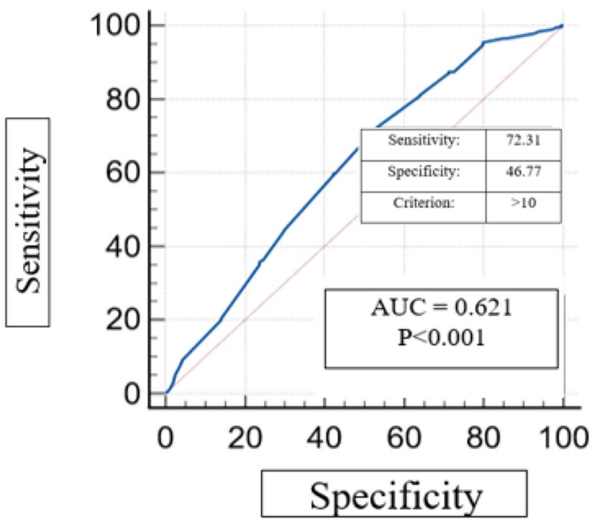

Fig. 2 ROC curve demonstrating the diagnostic capability of the FM for identifying the causative jaw in Angle II patients, as evaluated by GP dentists

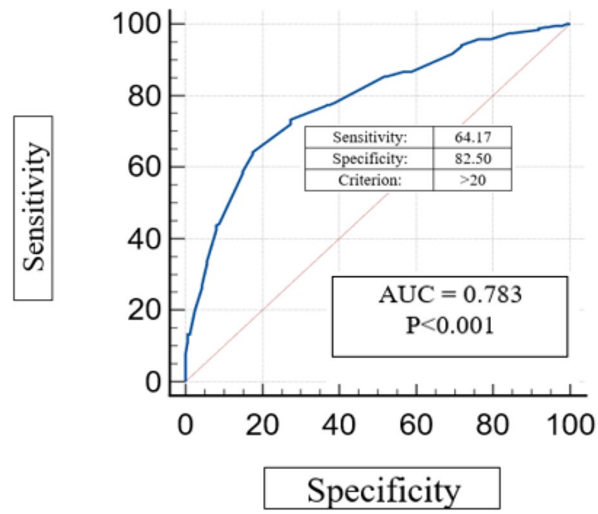

Fig. 3 ROC curve illustrating the diagnostic capability of the Fränkel manoeuvre for identifying the causative jaw in Angle II patients, as assessed by orthodontists

Cephalometric study of patients

Cephalometric analysis of the patients whose photographs were included revealed that out of 10 patients, 6 (60%) had mandibular retrusion, and the remaining 4 (40%) had maxillary protrusion.

Analysis of data from GP dentists

The average "profile improvement" score (T1-T0) for the FM among GPs was approximately 21.4 for patients with mandibular retrognathia and 13.5 for patients with maxillary retrognathia. Student's t test revealed that the "improvement" score after the manoeuvre was significantly greater in patients with mandibular retrognathia than in patients with maxillary retrognathia ($P=0.0159$; Table 1).

ROC analysis (Fig. 2) revealed that, according to the assessment of GPs, a profile improvement score exceeding 10 (the highest "threshold") was indicative of Class II malocclusion caused by mandibular retrusion. However, when the 'profile improvement' score was 10 or less, Class II malocclusion was attributed to maxillary protrusion. The 'threshold value' with the highest sensitivity and specificity was considered the one that could distinguish which jaw anomaly was responsible for skeletal Class II malocclusion. The power of this prediction, overlapping with the AUC, was 0.62, signifying a weak predictive ability.

Analysis of data from orthodontists

The mean "profile improvement" score (T1-T0) for the FM, as assessed by orthodontists, was approximately 29.4 for patients with mandibular retrognathia and 5 for patients with maxillary retrognathia. Student's t test revealed that the 'improvement' score after the manoeuvre was significantly greater in patients with mandibular retrognathia than in those with maxillary retrognathia ($P<0.0001$; Table 2).

ROC analysis (Fig. 3) revealed that, according to orthodontists, when the 'improvement' score exceeded 20 (the highest "threshold"), Class II malocclusion was attributed to mandibular retrusion, but when the 'improvement' score was 20 or less, Class II malocclusion was linked to maxillary protrusion. The predictive power, consistent with the AUC, was 0.78, indicating good predictive ability.

Discussion

This study aimed to assess the diagnostic potential of the FM for identifying the causal jaw in Class II Division 1 malocclusion comparing it with lateral cephalometry, which is considered the reference standard. Notably, Paduano et al. [12] demonstrated that a patient performed FM in the context of Class II Division 2. However, our study exclusively included patients with Class II Division 1 malocclusion. This selective inclusion was deliberate, as division 2 presents challenges due to palatal incisor inclination, obstructing mandibular displacement and serving as a physical barrier to the FM [13]. The causative jaw was determined using the Steiner and McNamara analyses. Notably, the majority of our sample (60%) exhibited mandibular retrusion, while 40% displayed maxillary protrusion. These proportions closely align with the typical distribution observed in the general population for subjects with normal Angle Class II malocclusion [2, 14, 15].

According to the results, approximately half of the orthodontists in the study relied solely on cephalometry to identify the causative jaw in Angle Class II. Approximately one-third use a combination of cephalometry and clinical methods, such as FM or an extraoral facial examination. The remaining small minority depends on clinical methods alone. Notably, while there is limited information in the scientific literature regarding the distribution of diagnostic methods used, soft tissue and aesthetic assessments are considered crucial in modern orthodontics for evaluating cephalometric parameters [16]. Because of the individual variances in thickness of the soft tissue, it is shown that it has a significant influence on facial profile and behaves independently from the underlying skeleton [17]. This could explain the different results between the cephalometrics and FM evaluation. Finding out which analysis is best suited to achieve diagnosis and, in turn, a suitable treatment plan, becomes relevant. The needs of orthodontic patients are mostly aesthetic needs [17], and one of the potential advantages of FM is the possibility of evaluating the perceived facial aesthetic. On the contrary, skeletal pattern imbalance does not necessarily correspond to undesirable aesthetics.

The influence of FM on facial aesthetics was investigated among Lithuanian GP dentists and orthodontists. According to the results of this study, the mean improvement score after the manoeuvre was significantly greater for mandibular retrusion than for maxillary protrusion, as assessed by both orthodontists (29.4 vs. 5) and GPs (21.4 vs. 13.5). These findings are consistent with those reported by Ahrari et al. [9]. Therefore, FM is associated with a more harmonious facial profile and significantly better aesthetics in patients with a retrognathic mandible and a normal maxillary position. Deterioration of the profile during FM is associated with a biprognathic jaw position, where the mandible adapts to the protruding (prognathic) maxilla. According to Martina et al. [2], although the assessment of the manoeuvre may seem very subjective, it can be replicated with a high degree of precision, without the need for clinical experience.

In terms of the diagnostic accuracy of the manoeuvre, a higher diagnostic accuracy was observed for the orthodontist group. The prognostic power of the parameters was assessed by the area under the curve (AUC), an index of how well the parameter can distinguish between two diagnostic groups (maxillary prognathia/mandibular retrognathia) [18]. GP dentists rated the sensitivity and specificity of the Fränkel manoeuvre for identifying these diagnostic groups at 72% and 47%, respectively, while orthodontists rated it at 64% and 82%, respectively. The area under the curve (AUC) was 0.62 for GPs and 0.78 for orthodontists. The assessment of the AUC showed that the manoeuvre is not perfect but rather useful for diagnosing skeletal Angle Class II occlusions (mandibular retrognathia or maxillary prognathia). It is crucial to note that achieving 100% accuracy necessitates the entire AUC, and the ROC curve should be fully shifted to the upper-left corner of the graph [19].

The greater diagnostic accuracy of the FM used by orthodontists could be attributed to the experience of the study participants. Among orthodontists, less than one-third had less than 5 years of experience, while almost half (45%) of the GPs had less than 5 years of experience. Ahrari et al. [9] emphasised the importance of matching factors such as the number of doctors, age, sex, and clinical experience to minimise potential confounding effects. Martina et al. [2] categorised doctors into two groups—those with less than 5 years of experience and those with more than 5 years of experience—and found that the difference in scores was not statistically significant ($p > 0.05$). However, in our study, the groups were not separated by seniority, and the results were calculated under the assumption that clinical experience should not significantly influence the outcomes [2].

In this study, the FM was compared with two-dimensional (2D) cephalometric analysis as a reference standard. Quan et al. [20] performed a meta-analysis investigating the differences and accuracy between 2D and 3D cephalometric tests. They concluded that the accuracy of the images obtained from cone beam computed tomography (CBCT) scans is comparable to that of conventional cephalometric measurements. However, differences between two skeletal parameters (Ar(Co)-Gn, Me-Go) and one dental parameter (U1-L1) were found to be statistically significant between CBCT and conventional cephalograms ($P = 0.000$, $P = 0.004$, $P = 0.000$, respectively). According to Sam et al. [21], to assess the performance of 3D cephalometric landmarks in assessing the reliability of 3D craniofacial complexes, further research is needed. Therefore, CBCT is recommended as a complementary tool when improved diagnosis is needed in the present circumstances and during treatment planning [20].

Rongo et al. [10] conducted a study comparing FM performed on two-dimensional and three-dimensional images. A comparison of the 2D and 3D images revealed that the reliability of the 2D images was greater than that of the 3D images of the FM in stereo photography. This study has several inherent limitations. First, only 10 patients' photos were included in the study, and the sample size comprising GPs and orthodontists was relatively small; therefore, the work was only eligible for the pilot requirements. Second, there was no accurate validation tool available for identifying the causative jaw in Class II malocclusion patients, as cephalometry also has some limitations in the diagnostic process [4–6, 21, 22]. Third, according to Lo Giudice et al. [17], patients who are hyperdivergent, have statistically thicker cortical bone than normodivergent and hypodivergent patients, therefore aesthethic assessment of the FM might differ according to the facial pattern. Finally, the present study design does not allow us to conclude that similar results can be obtained between the outcome of the manoeuvre and the outcome of the treatment.

Conclusions

1. The Fränkel manoeuvre method has proven to be a valuable tool in the diagnosis of skeletal Angle Class II malocclusion etiology (mandibular retrognathia or maxillary prognathia).

2. The sensitivity and specificity of Fränkel's manoeuvre for detecting skeletal Class II Division 1 etiology were 72% and 47%, respectively (AUC 0.62), for GP dentists and orthodontists were 64% and 82%, respectively (AUC 0.78). Therefore, orthodontists using this manoeuvre demonstrate greater accuracy in diagnosing the causative jaw than GPs do.
3. The FM is a simple, adaptable and reliable clinical tool to identify the aetiology of skeletal Class II malocclusion and to predict the outcome of treatment for the facial profile. As it has some limitations, this test can be used as an alternative to cephalometric analysis in cases where cephalograms have not yet been performed, e.g. at the first visit, or when misleading results are obtained that are not consistent with the clinical examination.

Abbreviations

FM	Fränkel manoeuvre
GP	General practitioner
ROC	Receiver operating characteristic
AUC	The area under the curve
SD	Standard deviation
SN	Sella-Nasion
FH	Frankfort Horizontal
SNA	Sella-Nasion-A point
SNB	Sella-Nasion-B point
CBCT	Computed tomography

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Author contributions
N.S. and G.T. came up with the idea for the study, N.S., K.K., D.S., A.V., K.L., G.T. took part in its planning, and contributed to the manuscript's drafting. N.S. carried out the clinical measurements and performed statistical analysis. All authors participated in the writing process, read and approved the final manuscript.

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Data availability
On reasonable request, all data generated or analysed during the current study are available from the corresponding authors.

Declarations

Ethics approval and consent to participate
All participants volunteered for the study, were informed about the scope of the study, and provided written informed consent to participate in the study. The study was approved by the ethics committee of Bioethics Centre of the Lithuanian University of Health Sciences (Approval No. BEC-OF14, dated 09/09/2022).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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