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Review article

Evaluation of foot analysis in the presence of dental malocclusion: A systematic review

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ABSTRACT

Background: *Previous studies have reported that the imbalance of occlusion, cervical spine, length of the limb, and asymmetric leg length are related to the presence of muscle compensation. These issues influence some strategies in orthodontic diagnosis for developing an updated stomatognathic system over multidisciplinary care issues.* ***Purpose:*** *This study aimed to obtain orthodontic findings and an orthopedic relationship between foot posture/function and dental malocclusion based on cross-sectional studies.* ***Review:*** *Some findings about postural system disequilibrium in static and dynamic foot postural related to occlusal changes have been reported following the mixed dentition phase. From 248 articles, 5 articles were selected and assessed with the Joanna Briggs Institute critical appraisal cross-sectional checklist and analyzed.* ***Conclusions:*** *Although the selected eligible articles demonstrated a low risk of bias in agreement ($p > 0.05$) among authors, the evaluation of those cross-sectional studies is still limited and requires further longitudinal studies with precise diagnostic parameters. Those parameters for evaluating the relationship between foot posture and malocclusion should encompass both static and dynamic approaches, including those related to mandibular position, tongue posture and function, bad habits, and temporomandibular disorder.*

Keywords: *dental; foot; gait; malocclusion; posture*

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INTRODUCTION

The role of chain reactions in postural issues influences muscle function and alignment and potentially causes malocclusion. Concurrently, these postural problems may also influence overall metabolic functions, affecting bone growth and development.[1] This complex interplay highlights how seemingly unrelated factors may intricately impact dental and skeletal health through diverse physiological pathways. According to a cross-sectional study of 202 Thai children, which was conducted to determine the etiology of malocclusions, postural disorder as an acquired etiology factor played a greater role than congenital and idiopathic factors.[2] The high demand for preventive, interceptive, and corrective orthodontic treatment in correcting malocclusion from childhood to adulthood with referral patterns has shown rapid advances in diagnostic and treatment approaches.[2] Orthodontists should be aware of the quality of a patient's life based on perception and assist health professionals to arrange and adapt proper individualized orthodontic treatment.[3,4] Investigations into how orthodontic treatment can be a part of an integrated treatment to accomplish overall functional and esthetic value with stability attainment in holistic wellness sustainability led to a multidisciplinary treatment approach while treating patients with malocclusion.

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Although the imbalance of occlusion and posture is always present in patients with (and even sometimes without) craniofacial syndromes, understanding the association of the dental–craniofacial aspect and posture of human beings in orthodontics requires multidisciplinary care.[5-8] In studies of the etiopathogenesis and treatment of any malocclusions accompanying craniofacial disorder, nodal pathway genes downregulated in facial asymmetry were a common finding in skeletal examinations.[9] The imbalance of occlusion, cervical spine, length of the limb, and asymmetric leg length is related to the presence of muscle compensation. It changes posture gradually and affects the plantar position, which becomes the center of foot pressure and gait stability.[10-13] Hence, recent studies have also suggested that orthodontists should conduct specialized investigations for patients exhibiting spinal deformities.[11-15] Even if there were occlusal factors and postural alterations, the scientific evidence to support the cause–effect relationship was still limited to postural graph analysis and was not conducted in daily orthodontic diagnosis routinely. The role of morphological features in the dental and skeletal relationship due to mandibular position may serve as valuable odontoid prediction markers among children in multidisciplinary orthopedic orthodontics that focus on the body posture and craniofacial parameters in the cervical spine relationship.[6,12-14,16]

Malocclusion and body equilibrium studies, especially malocclusion related to gait biomechanics in adolescents in the scientific dental community, are still limited and controversial. The orthodontic treatment itself is not sufficient for correcting overall dysfunction that possibly was generated by malocclusion, which is multifactorial and originating from genetics, environmental, and postural elements.[9,13] The study of the effect of jaw position on postural stability in healthy men reported that the jaw sensory-motor system can modulate postural stability and mechanisms based on different jaw positions.[16,17] In contemporary orthodontic research, there is a growing understanding of the connection between tongue function and the body's overall equilibrium. Consequently, the causal relationship between changes in occlusion and body posture significantly influences the balance of the stomatognathic system, intricately intertwining with the broader postural equilibrium. Thus, any imbalanced posture of the cervical column can impact the dorsal part negatively and influence different parts of the body vertically. The aberrant position of the cranium can lead to compensation of dorsal level due to overloading of the tongue position, mandibular, and cervical column and activation of muscle chains in the physiological pathways of the stomatognathic system, including leg position and posture.[18-20]

Considering the leg and foot posture during a musculoskeletal system examination is recommended if it presents signs of temporomandibular joint disorder (TMD). The functional relationship between mastication and leg muscles, as assessed through electromyography, has been reported after artificially inducing interdental occlusal dysfunction.[7,12,13,20,21] The limited available evidence also reported that in preventing or treating postural body imbalance, asymmetry in the stomatognathic system may be observed.[22] Thus, this study aims to evaluate previous studies about dental malocclusion findings and foot posture based on literature findings from multidisciplinary cross-sectional studies.

METHODS

This current literature protocol has been registered in the International Prospective Register of Systematic Reviews (PROSPERO ID: CRD42023412106). This approach was agreed with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA-P).[23] Some studies that were eligible in the qualitative synthesis (systematic review) according to the elements were performed to answer the focused question, "How is the relationship of foot analysis in the dental malocclusion presence", as follows: Population: childhood to adulthood. Exposure: patients who came for a dental routine check-up. Comparison: various types of dental malocclusion based on Angle's molar classification and foot posture index. Outcomes: orthodontic findings based on malocclusion characteristics and orthopedic analysis based on foot posture that related to gait parameters.

This study fulfilled the inclusion criteria for researchable questions from previous studies between 2013 and 2023 based on the population, exposure, comparison, and outcome structure. The criteria were as follows: (1) participants of these studies were healthy individuals drawn from childhood to adulthood, (2) the exposure groups were patients who came for a dental routine check-up and had complete upper and lower molar permanent teeth, (3) the comparison groups were based on Angle's classification of molar relationship and foot posture index, and (4) the literature was in the English language, with only cross-sectional studies.[24]

This study included medical journals that were identified with advanced searches in Google Scholar (https://scholar.

Table 1. Search strategy to identify the relationship between foot analysis and dental malocclusion

Database	Search	Items found
Google Scholar	malocclusion gait foot "cross-sectional"	248
ProQuest	malocclusion AND foot AND gait AND cross-sectional	38
LILACS/MEDLINE	(malocclusion) AND (foot) AND (gait)	3
PubMed	malocclusion AND foot AND gait	2

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google.com/scholar), ProQuest (https://www.proquest.com), LILACS/MEDLINE (https://lilacs.bvsalud.org/en/#NETWORK), and PubMed (https://pubmed.ncbi.nlm.nih.gov/) using the following keywords: malocclusion, foot, and gait. The selected keywords were based on medical subject headings terms from https://www.ncbi.nlm.nih.gov/mesh/ from cross-sectional studies (Table 1). After including the selected articles for systematic reviews with PRISMA-P, the Joanna Briggs Institute (JBI) critical appraisal tools for cross-sectional studies were used by the authors to assess the methodological quality of those studies.[25] The differences in JBI agreement among authors were conducted with a multivariate ANOVA test with STATCAL (https://statcal.com/).

RESULTS

According to the PRISMA flow diagram for systematic review, only five articles fulfilled the inclusion criteria for analysis (Figure 1). Table 1 shows the sources of some eligible studies that fulfilled the qualitative study requirement in answering the focus research and were analyzed with the JBI checklist for cross-sectional studies.[23] From those five articles, the framework procedural analysis was conducted by the dental clinician, orthodontist, prosthodontist, and podiatrist.[26-30] All the significant values on Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root showed a value of >0.05, and it was concluded that there was no difference in the assessment of those authors towards the five articles (Table 2).

Figure 2 demonstrates the evaluation of the relationship between orthodontic parameters (skeletal and dental classification) and orthopedic findings (foot posture/function) in static assessment. Skeletal dental relationships in orthodontic diagnoses are based on Class I, Class II, and Class III malocclusion. The foot analysis is based on the foot posture index, which is used as a diagnostic clinical tool in quantifying the degree of foot position in six clinical criteria employed, as follows: Category 1: talar head palpation; Category 2: supra and infra lateral malleolar curvature; Category 3: calcaneal frontal plane position; Category 4: prominence in the region of the talonavicular joint; Category 5: congruence of the medial longitudinal arch; Category 6: abduction/adduction of the forefoot on the rearfoot.[31]

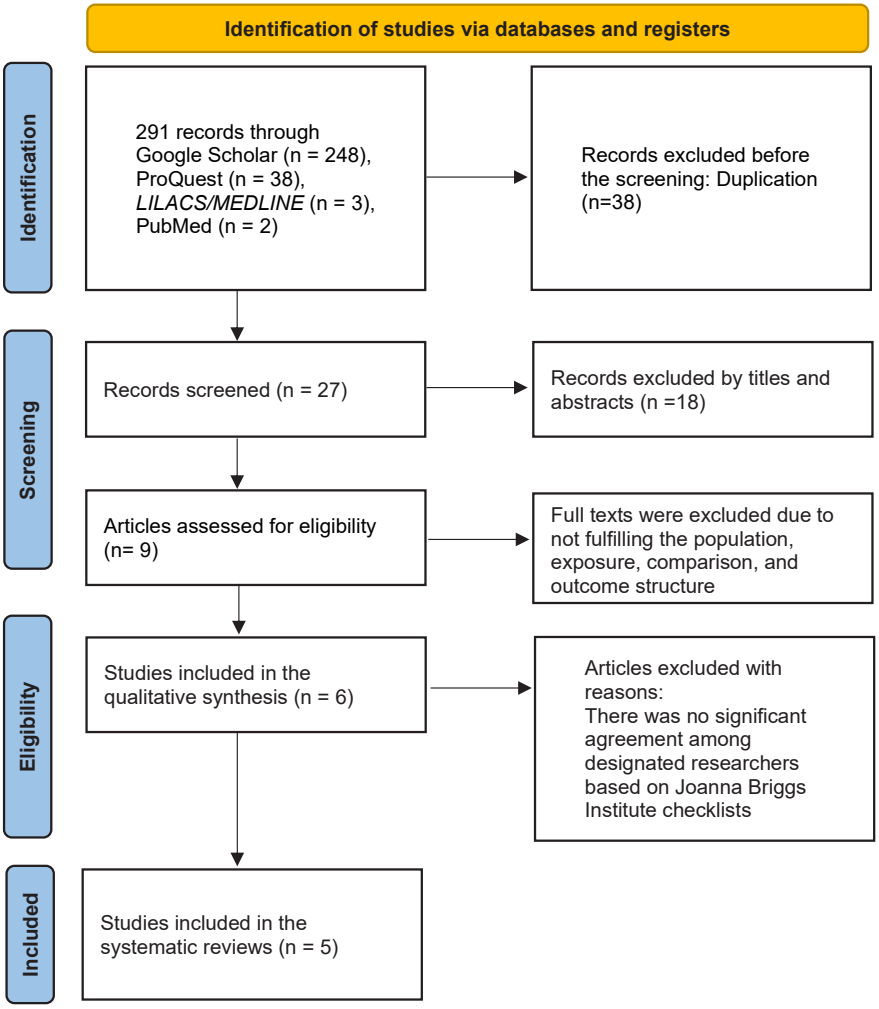

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram for systematic review.

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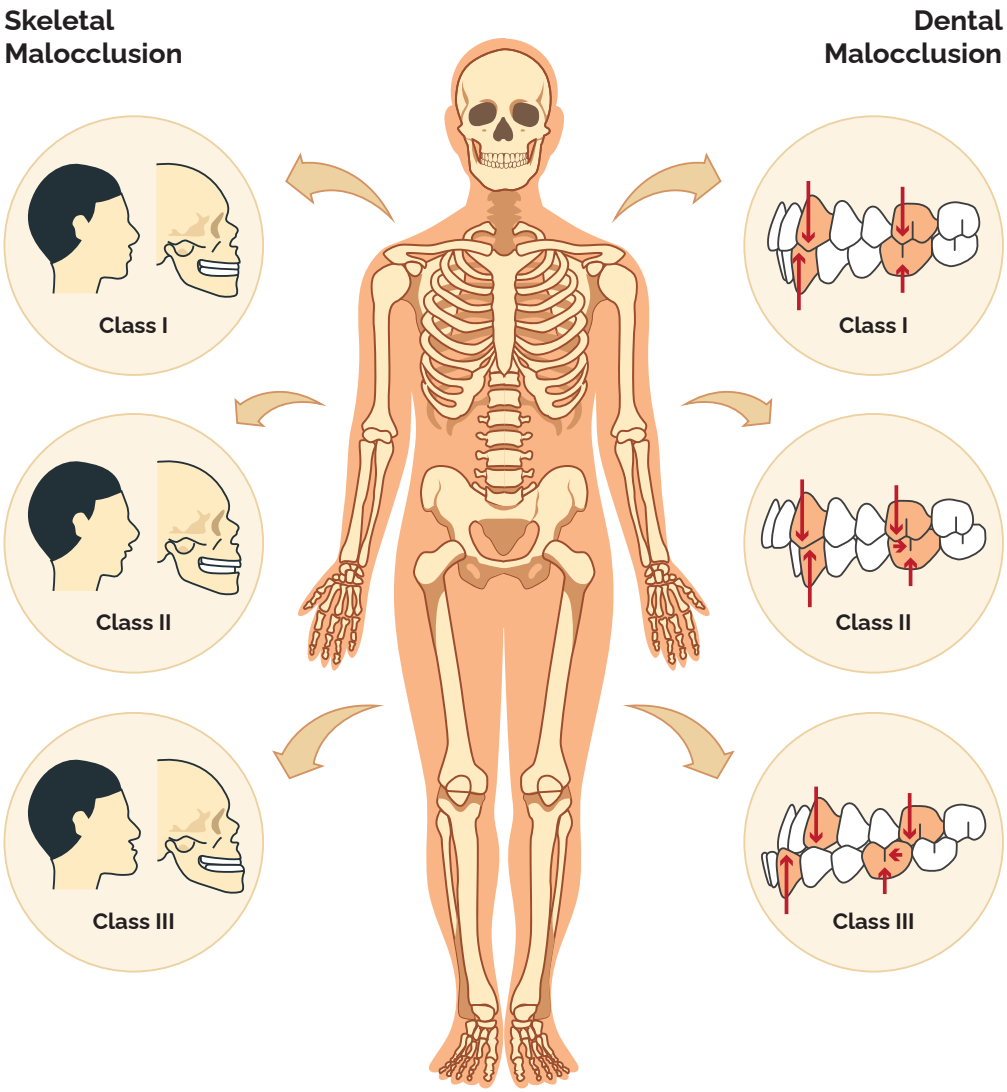
Table 2. Multivariate ANOVA tests for authors' bias assessment for the five articles that were included in the systematic reviews

	Effect	Value	F	Hypothesis df	Error df	*p*
Authors' assessment	Pillai's Trace	0.175	0.898	6.000	56.000	0.503*
	Wilks' Lambda	0.827	0.894[a]	6.000	54.000	0.506*
	Hotelling's Trace	0.205	0.888	6.000	52.000	0.511*
	Roy's Largest Root	0.186	1.732[b]	3.000	28.000	0.183*

Note: p>0.05; Inter-rater reliability for authors' bias assessment is accepted



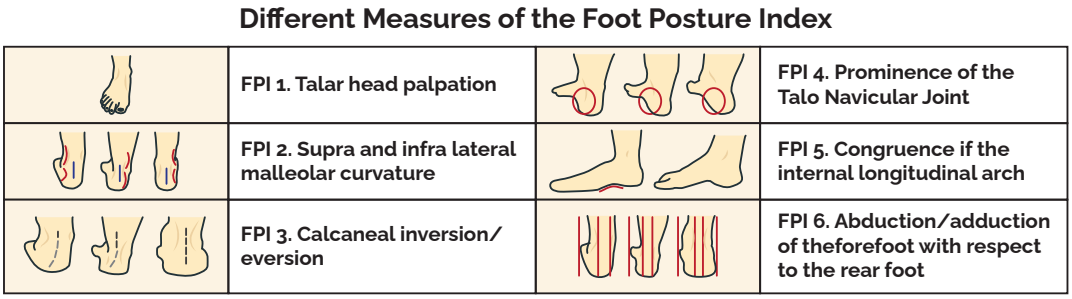


Figure 2. Static analysis between the presence of orthodontic (skeletal and dental classification) and orthopedic findings (foot posture/ function). (Private documentation).

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DISCUSSION

A limited number of primary studies analyzing the characteristics and pathophysiology of this phenomenon led to explore additional studies of postural analysis to obtain adequate orthodontic diagnoses. This systematic review was conducted to strengthen or clarify conclusions previously published on a particular topic by increasing the statistical power of collective analysis. Any evidence-based study that supports evidence-based practice among health service decision-makers should rely on external evidence, clinical expertise, and the patient's willingness to participate.[32,33]

Early detection of this phenomenon could alter the basic gnathology and should be examined comprehensively in three dimensions. As presented in Table 2, the assessments

Table 3. Description of selected articles included in the systematic reviews

Author, year	Setting and characteristic study sample	Framework procedural analysis	Outcome data
Marchena-Rodriguez et al., 2018[26]	Primary school students aged 6–9 years in Malaga province public school, Spain without following history, such as surgery of the lower limbs or the upper body, the presence of certain postural habits altering the child`s initial posture, orthodontics and/or orthosis treatment, or non-emergence of sufficient teeth to determine the dental classifications	1. Questionnaires in observing the childrens' postural habits, including oral and posture bad habits 2. Foot posture index (FPI) and Clarke angles analysis by the podiatrist 3. Molar relationship on Angle classification by the orthodontist	There was a significant relationship ($p < 0.01$) between forefoot and hindfoot pressure Angle classification molar relationship.
Nowak et al., 2023[27]	Outgoing patients' clinic with patients aged 19–35 years in Poland with the following criteria: Complete permanent teeth, except third molar; never had treatment that could affect gait and body balance.	1. Clinical functional analysis of temporomandibular dysfunction based on the RDC/TMD protocol 2. Classification of Angle's molar relationship 3. Stabilography and analysis of the ground reaction forces during standing and gait were performed using a baropodometric platform	52 female and 38 male patients show significant relationship between dental occlusion and postural analysis while static, whereas no relationship in dynamic test.
Rozanska-Perlinska et al., 2023[28]	Dental routine patients aged 12–15 years; healthy, without orthodontic or orthopedic treatment history, severe trauma, or surgery.	1. Weight measurement 2. Height measurement 3. Analyzing the distribution of foot forces 4. Gait analysis 5. Three-dimension postural analysis	From 40 boys and 36 girls, patients with malocclusion showed no significant asymmetry in the podal system and gait analysis.
Perez-Belloso et al., 2020[29]	Primary school students aged 8–14 years in Seville province public school, Spain, without following history such as surgery of the lower limbs or the upper body, the presence of certain postural habits altering the child`s initial posture, orthodontics and/or orthosis treatment, or non-emergence of sufficient teeth to determine the dental classifications.	1. Using the FPI 2. The height of the truncated scaphoid 3. Plantar pressure with baropodometric measurement by the podiatrist 4. Angle's molar dental relationship by the dental specialist	Of 158 boys and 131 girls, there was no significant relationship between dental malocclusion and gait typology.
Cabrera-Dominguez et al., 2021[30]	Primary school students aged 8–14 years in various schools at Seville province, Spain without previous orthodontic treatment or systemic conditions that may affect the results and without having undergone operations on the lower extremities or upper part of the body, presenting proven disorders in terms of the vertebral column, having had orthodontic treatment, having had any trauma that has modified the posture, or lacking the teeth necessary to determine Angle's classification.	1. Sagittal molar relationship 2. Foot posture index 3. Truncation of the scaphoid 4. Plantar pressure with baropodometric measurement by a podiatrist	From 222 boys and 187 girls, there was no relationship between the hip position and the molar relationship.

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should be performed by a multidisciplinary team, such as physicians, dentists, orthodontists, orthopedic surgeons, physiotherapists, medical rehabilitation, and even podiatrists. Any interest, support, and participation in this new paradigm offers a comprehensive perspective and stimulates dental clinicians' behavior, preferences, intentions, attitudes, and opinions to improve dental–medical health policies. This comprehensive diagnosis for individuals with malocclusion can develop a change of static equilibrium but is not significant in a dynamic evaluation, especially in gait analysis (Table 3). The postural imbalances found in a comprehensive analysis of head, tongue, cervical, spine, lumbosacral, upper, and lower limbs based on recommendations of previous studies about postural parameters could attribute the sample segmentations for different subgroups in a wide-ranging population.[5,11,12,28,29]

The selected articles also reported the absence of cephalometric analysis, which may be seen as a failure to consider the effects of natural change in growing samples and limited the comprehensive orthodontic analysis. According to structural researchable questions, Table 3 demonstrated that this study has identified, appraised, and synthesized previous empirical cross-sectional studies about foot analysis/function in the presence of dental malocclusion and reported the presence of significant correlation in static rather than dynamic dimensions as thoroughly as previous studies.[26-30] Although the occlusion of the dentition has been established, some minor changes affect the interrelationship of dental and skeletal in sagittal, transverse, and vertical interrelationships. These studies focused on static dental relationships based on molar classification. However, compensation of the dorsal level in the growing phase will require longitudinal studies. Therefore, evaluation of malocclusion and posture-graphic platform of the medical and dental center policy should be advised, as in previous studies in other countries.[5,20,27-29]

Postural alterations that potentially impact mandibular position and facial morphology include cervical spine disorders, pelvic and thoracic inclinations, pelvic rotation, and imbalances in body muscles. These have a relationship with foot posture and balance, which can be assessed with diagnostic instruments, such as a foot pressure platform, to measure kinematic posture, stabilometric parameters, and three-dimensional posture.[27,30] However, there was only one selected article that disagreed with this researchable question due to a different study design.[26] These studies explained that the selected five articles about evaluation foot analysis in dental malocclusion presence showed limitations in controlled design and sample characteristics. Further studies are needed to understand the complexity of asymmetry that is related to a patient's locomotory organs, involving myofascial chains and the distal effect on the structure and stability of any organ posture in humans. Our findings can explain the compensation between occlusal change and trunk–dorsal mechanism should be considered due to minor and gradual changes. This condition may affect the genetic expression of the interrelationship between dental and skeletal in sagittal, transverse, and vertical interrelationships.

The presence of stomatognathic disorder and gait cycle parameters was also induced by an imbalance of mandibular to maxillary position that was also influenced by tongue posture and function. The functional relationship between mastication and leg muscles based on electromyography examination has been reported after artificially creating interdental occlusal dysfunction.[21,26] Any imbalanced posture of the cervical column also could indirectly impact the compensation of the dorsal level due to overloading of the tongue position, cervical column, and activation of muscle chains in the stomatognathic system that may lead to malocclusion and TMD.[18,21] For patients with TMD, leg length discrepancies within the musculoskeletal system should be examined.[21,34]

Even though the selected eligible articles demonstrated a low risk of bias in agreement ($p > 0.05$) among authors, the evaluation of those cross-sectional studies is still limited and requires further longitudinal studies with precise diagnostic techniques, such as skeletal malocclusion analysis, particularly those related to mandibular position, tongue posture and function, bad habit, and temporomandibular disorder. There was no direct relationship between foot pressure or posture and dental malocclusion only. This evidence-based study will enhance the strategy for developing precise diagnostic parameters that affect the upper and lower limbs in non-syndromic patients such as asymmetry of leg length or foot loading distribution in a static position in longitudinal studies.

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