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The relationship between malocclusion and speech patterns: a cross-sectional study

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Abstract

Objective Dental occlusion and the alignment of the dentition play crucial roles in producing speech sounds. The Arabic language is specifically complex, with many varieties and geographically dependent dialects. This study investigated the relationship between malocclusion and speech abnormalities in the form of misarticulations of Arabic sounds.

Materials and methods One hundred native subjects (28.92 ± 12.09 years old) were recruited for this cross-sectional study. The Peer Assessment Rating (PAR) index was used to describe malocclusion pattern. A standard speech sample was recorded for each subject and evaluated by a blinded speech therapist to judge misarticulations and indicate the misarticulation classification. The Jeddah Institute for Speech and Hearing Centre (JISH) articulation test was used to assess the phonologic abilities of the participants. Mann-Whitney U test was utilized for the statistical analysis. *P*-value < 0.05 was considered statistically significant.

Results The PAR score ranged from 0 to 15, with an average of 4.87. The descriptive statistics of the included sample demonstrated that twenty-seven subjects showed improper articulation of sounds, with 25 being distortions and 2 substitutions. No significant gender differences were reported. A statistically significant association between PAR scores was recorded for the sounds / ص/ ($p = 0.004$), / ز/ ($p = 0.017$), and / س/ ($p = 0.010$).

Conclusions There was an evident pattern of partial association of PAR index scores and speech abnormalities including improper articulation. To provide optimal care for involved subjects, collaboration between orthodontists and speech therapists, in pre- and post-treatment evaluations, is crucial.

Keywords Malocclusion, Speech misarticulations, Arabic letters, PAR Index

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Introduction

Speech and phonetics are complex psychophysiological processes of putting sounds into words and organizing them into a predefined sequence with specific grammatical and symbolic context. Although it may seem simple, normal speaking and clear communication are not easy. It requires precise timing as well as control over multiple muscles and nerves [1, 2]. Speaking clearly is a learned habitual neuromuscular pattern. The role of dentition in speech has been well-established in the literature. Certain sounds are more affected by dental abnormalities than others, and this primarily depends on the precise regions where the sound originates [2, 3].

The relationship between dental occlusion and speech patterns is multifaceted. Normal speech relies heavily on the correct coordination between the involved articulatory oral structures, including the tongue, lips, and jaws, to produce logical sounds [4–6]. Dental anomalies and abnormal occlusion are thus expected to cause alterations in the positioning and movement of these structures, consequently impacting speech production. Malocclusions, such as anterior open bites or crossbites, affect articulatory movements, resulting in distortions, substitutions, or omissions of speech sounds. Other craniofacial anomalies, such as clefts, can contribute to orofacial muscular tension and imbalances, resulting in speech difficulties [6–8].

Previous reports indicated that speech sound disorders (SSD) in school children were significantly associated with dental malocclusions (Angle Class II and III, anterior open bite, edge-to-edge bite, overjet and anterior crossbite) because of the imbalances in the functions involved in the stomatognathic system [9, 10]. Another study revealed that children with SSD had both poorer orofacial function and a greater prevalence of malocclusion than children with typical speech development [11]. In a sample of adult population, Class II and III patients had higher prevalence of qualitative distortions and spectral changes in consonants compared to controls. It was concluded that the linear correlations between anterior-posterior jaw disproportions and spectral change suggest causation and that treatment may improve articulation problems [12].

Arabic language is recognized for its unique complexity in characters and sounds. One notable aspect contributing to its complexity is its system of roots and patterns, where words are derived by manipulating consonantal roots and vowel patterns, resulting in a high degree of lexical variations and rich vocabulary. In addition, Arabic language exhibits an exceptionally complex phonological system [13, 14]. Speech and phonetics considerations should be incorporated into the pre- and post-treatment evaluation in order to ensure the best possible holistic dental and orthodontic treatment for patients. The current study investigated the relationship between malocclusion, as defined by the Peer Assessment Rating (PAR) index, and speech abnormalities in misarticulations of Arabic sounds.

Materials and methods

This cross-sectional study was conducted in Riyadh Elm University (REU) in Riyadh, KSA. The study sample comprised of one hundred subjects who were all native Arabic speakers. The subjects were recruited from the outpatient clinic of the College of Medicine and Dentistry, REU, KSA. All subjects had full permanent dentition. Exclusion criteria were subjects with craniofacial deformities, previous orthodontic treatment, extensive carious lesions, dental wear, history of dental trauma/fractures, prosthetic treatments such as crowns/veneers, diagnosed speech impediments, or missing permanent teeth. Written consent was obtained from all subjects before participation in the study, and the project was approved by the Ethical Committee of Riyadh Elm University (SRP/2021/54/463/440).

The subjects were examined clinically for malocclusions using the PAR index, a standardized index consisting of upper and lower labial segment alignment measurements, anteroposterior buccal occlusion, transverse buccal occlusion, vertical buccal occlusion, overbite, overjet, and midlines (Table 1).

The study utilized an Arabic speech development standardized test (the JISH Articulation test, JAT) designed to assess the phonological abilities of participants. The JAT is an assessment tool developed by the Jeddah Institute for Speech and Hearing Centre (JISH) to assess speech development and articulation. The test assesses each letter of the Arabic language with three words in which the sound is found at the beginning, middle, and end of the word and is suitable primarily for the Saudi accent and other Arabic accents [15]. The test was conducted by an investigator (NT) who was well-trained and calibrated before the start of the study to ensure reliability. If any misarticulation was noted, a further evaluation was taken with the relevant sound presented multiple times in a standardized paragraph. A single evaluating speech therapist, blinded to the malocclusions present, evaluated the video recordings of the responses to confirm the presence or absence of misarticulations and indicated the misarticulation classification. The responses and sounds were logged and compared to normal subjects. Misarticulations were classified as omission (absence of the required sound), substitution (replacing a sound with another correct sound), addition (adding a speech sound next to the correct sound), and distortion (inaccurate pronunciation of speech sound) [16].

Table 1 PAR index description

Measurement	Description	Scoring
Upper and lower labial segment alignment	Contact point displacement	0: 0–1 mm 1: 1.1–2 mm 2: 2.1–4 mm 3: 4.1–8 mm 3 4: greater than 8 mm 5: Impacted (space between adjacent teeth is less than or equal to 4 mm)
Buccal occlusion	Anteroposterior	0: good interdigitation 1: less than one-half unit from full interdigitation 2: one half unit discrepancy on any tooth
	Transverse	0: no crossbite 1: crossbite tendency 2: a single tooth in crossbite 3: greater than one tooth in crossbite 4: greater than one tooth in a scissor bite
	Vertical	0: no posterior openbite 1: posterior openbite of more than 2 mm and on at least two teeth
Overjet	Positive overjet	0: 0–3 mm 1: 3.1–5 mm 2: 5.1–7 mm 3: 7.1–9 mm 4: greater than 9 mm
	Negative or reverse overjet	0: no anterior teeth in crossbite 1: one tooth or more edge to edge 2: a single tooth in crossbite 3: two teeth in crossbite 4: greater than 2 teeth in crossbite
Overbite	Overbite	0: less than one-third of the lower incisor is covered 1: greater than one-third of the lower incisor is covered but less than two thirds 2: greater than two-thirds of the lower incisor is covered 3: greater than or equal to full coverage of the lower incisor
	Open bite	0: no openbite 1: less than or equal to 1 mm 2: 1.1–2 mm 3: 2.1–4 mm
Midlines	Coincident midlines	0: coincident or up to one-quarter width of the lower incisor 1: one quarter to one-half width of the lower incisor 2: greater than one half-width of the lower incisor

The sample size needed for conducting this study was calculated using the G*Power 3.1 software. A sample size of 75 achieved 95% power with $\alpha = 0.05$ and effect size 1.76. Ten cases were randomly selected from the sample to be re-evaluated after two-weeks period to assess the reliability of the analysis and confirm a less than 10% discrepancy. Descriptive statistics of frequency distribution and percentages were calculated for the categorical variables. Means and standard deviations were obtained for the PAR index. Mann-Whitney U test was used for the analysis, and the Statistical Package for the Social Sciences (SPSS version 25, Armonk, NY) was utilized to analyze the results. *P*-value < 0.05 was considered statistically significant.

Results

A description of the study sample and included variables is presented in Table 2. The sample included one hundred subjects (mean age 28.92 ± 12.09 years) with a male-to-female ratio of 59/41. The PAR score ranged from 0 to 15, with an average of 4.87. The descriptive statistics of the PAR index with the multiple responses demonstrated that twenty-seven subjects showed improper articulation of sounds, with 25 being distortions and two substitutions, particularly in the letters /ث/, /ذ/, /ز/, /س/, /ش/, /ت/, /د/, /ص//. A total of 78 distortions were reported in the current study sample (Table 3). A statistically significant association between PAR scores was recorded for the sounds / ص/ ($p = 0.004$), / ز/ ($p = 0.017$) and / س/

Table 2 Characteristics of the study variables

		n	%
Gender	Female	41	41.0%
	Male	59	59.0%
Labial alignment	0 to 1 mm	34	34.0%
	1.1 to 2 mm	19	19.0%
	2.1 to 4 mm	33	33.0%
	4.1 to 8 mm	10	10.0%
	Greater than 8 mm	3	3.0%
	Impacted	1	1.0%
AP- Buccal Occlusion	Good interdigitation	60	60.0%
	Less than one-half unit from full interdigitation	16	16.0%
	One half-unit discrepancy on any tooth	24	24.0%
Transverse - Buccal Occlusion	No crossbite	87	87.0%
	Crossbite tendency	0	0.0%
	Single tooth in crossbite	4	4.0%
	Greater than one tooth in crossbite	8	8.0%
	Greater than one tooth in a scissor bite	1	1.0%
Vertical Occlusion- Buccal	No posterior open bite	87	87.0%
	Posterior open bite of more than 2 mm and on at least two teeth	13	13.0%
Positive Overjet	0 to 3 mm	58	58.0%
	3.1 to 5 mm	16	16.0%
	5.1 to 7 mm	13	13.0%
	7.1 to 9 mm	12	12.0%
	Greater than 9 mm	1	1.0%
Negative Overjet	No anterior teeth in crossbite	84	84.0%
	One tooth or more edge to edge	5	5.0%
	Single tooth in crossbite	4	4.0%
	Two teeth in crossbite	2	2.0%
	Greater than two teeth in crossbite	5	5.0%
Overbite	Less than one-third of the coverage of the lower incisor	67	67.0%
	Greater than one third but less than two-thirds coverage of the lower incisor	29	29.0%
	Greater than two-thirds coverage of the lower incisor	4	4.0%
Openbite	No open bite	79	79.0%
	Less than or equal to 1 mm	10	10.0%
	1.1 to 2 mm	8	8.0%
	2.1 to 4 mm	2	2.0%
	Greater than 4 mm	1	1.0%
Midlines	Coincident or up to one-quarter width of the lower incisor	61	61.0%
	One quarter to one half-width of the lower incisor	30	30.0%
	Greater than one half-width of the lower incisor	9	9.0%

($p=0.010$). No significant gender differences were reported in improper articulation with PAR score (Table 4).

Discussion

There are several categories of speech and sound production. Fricative sounds are produced by incomplete closure of the vocal tract with continuous expression. Plosives are the sounds produced with complete closure of the vocal tract followed by a sudden air release [2, 17]. Sounds can also be classified based on where it is produced, whether labial, bilabial, labiodental, interdental, alveolar, palatal, velar, or glottal [17]. Orthodontic treatment aligns teeth to improve facial aesthetics and oral functions. The anterior limit of the dental arch is crucial in determining the boundary of the tongue and,

Table 3 Analysis of the multiple response data

		Responses	
		N	Percent
Improper articulation[a]	ص	12	15.4%
	ز	18	23.1%
	س	13	16.7%
	ش	14	17.9%
	ج	7	9.0%
	ث	4	5.1%
	ذ	2	2.6%
	Others	8	10.3%
Total		78	100.0%

[a] Dichotomy group tabulated at value 1.

Table 4 Comparison of the PAR scores across the different variables using the Mann-Whitney test

Variables		Mean	SD	Mean ranks	*P*
Gender	Female	4.24	1.96	47.77	0.429
	Male	5.31	3.76	52.40	
ص	Proper articulation	4.52	2.99	47.44	**0.004**
	Improper articulation	7.42	3.48	72.96	
ز	Proper articulation	4.56	3.16	47.28	**0.017**
	Improper articulation	6.28	2.97	65.17	
س	Proper articulation	4.57	3.10	47.63	**0.010**
	Improper articulation	6.85	3.11	69.73	
ش	Proper articulation	4.65	3.01	48.79	0.142
	Improper articulation	6.21	3.93	61.00	
ج	Proper articulation	4.82	3.21	49.93	0.471
	Improper articulation	5.57	2.88	58.07	
ث	Proper articulation	4.85	3.22	50.19	0.616
	Improper articulation	5.25	2.22	58.00	
ذ	Proper articulation	4.90	3.21	50.78	0.524
	Improper articulation	3.50	0.71	36.75	
Others	Proper articulation	4.86	3.13	50.49	0.990
	Improper articulation	5.00	3.93	50.63	

therefore, affects speech and phonetics [2, 3]. Various dental anomalies and malocclusions have been associated with speech disturbances. Class II or III malocclusions, anterior openbites, increased overjets or overbites, and anterior spacing or crowding have all been found to influence speech differently [10–12]. In addition, orthodontic treatment using fixed or removable appliances can disrupt sounds like "ص" "س," or "ر," which depend on proper tongue positioning and airflow [18, 19]. There are also several distinctive letters and sounds in Arabic that are not similar to any other language such as letters غ/ض. The current study aimed to investigate the association between malocclusions and types of misarticulation of sounds in a cohort of native-Arabic-speaking subjects.

Several indices have been developed to assess orthodontic diagnosis and treatment needs. One of the most popular is the PAR index. The PAR index is considered a reliable and reproducible index regardless of the phase of treatment and has been used in the literature as a screening tool for orthodontic problems [20]. It comprises five scores: upper and lower labial segment alignment, buccal occlusion, overjet, overbite, and midlines. Each value is scored independently and then added to provide the overall PAR score [21]. In the current study, PAR index was used to indicate the malocclusion pattern of the included sample. Various approaches are available to determine disturbances when considering speech assessment [19]. The current study utilized the Jeddah Institute for Hearing and Speech (JISH) standardized Arabic test (the JISH Articulation Test, JAT), which is the most commonly used among Saudi speech-language pathologists. Prevalence data indicate that speech disturbance rates were between 3.6 to 6.3% in Saudi children less than 16 years old [22]. In the current study, an experienced speech therapist, who was blinded to the patient's identity and malocclusion, analyzed the recordings for assessment of the speech patterns using a standardized assessment tool for the Arabic language to record misarticulation patterns.

Association between misarticulations of the /s/ sound and CL II malocclusion has been previously reported [23]. An earlier study examined the association between articulatory speech disorders and occlusal anomalies in a group of Finnish-speaking adults and indicated that mesial molar occlusion and mandibular overjet were associated with misarticulation of medio-alveolar consonants and that the incorrectly pronounced sounds are produced too anteriorly [24]. The present study findings related to malocclusions support the distortion in the /s/ sound, with most of the distortions reported for the /s/, /z/ and the strong /ṣ/ sounds. However, it is important to note that malocclusion might not be the sole causative factor of speech deformity, it could only count as a strong contributing factor.

The most common malocclusions that negatively impact sound production are openbites and mandibular prognathism or retrognathism (Class II or Class III) skeletal relationships [2, 25]. Openbites (even as little as 2 mm) significantly influence speech, with the sounds most affected being /s/ and /t/ [3, 26]. Since around 90% of consonant sounds are produced in the anterior portion of the oral cavity, abnormal teeth positions were expected to affect speech patterns in the studied sample. The Arabic letter (Sad) / ṣ/ is an emphatic and pharyngealized version of the /s/ sound and has no equivalent in other

languages. This letter specifically demonstrated the most significant distortion in the current study.

This study has potential limitations. The sample only included Saudi subjects which limits validity and generalizability of the findings. In addition, confounding factors such as including a few adolescent subjects might impact reliability of the data. It is known from the literature that all motor functions in human body follow certain developmental trajectories, for example an adult-like chewing motor behaviour is usually acquired during 15-18 years of age. Similarly, adult-like speech motor development is usually not acquired in adolescents, where previous literature showed that it can be acquired later in life [27]. Future research that addresses these identified gaps is essential.

Conclusion

Understanding the interplay between dental occlusion and speech abnormalities is critical for optimal diagnosis and management of speech disorders. Most of these disorders necessitate interdisciplinary collaboration between dental clinicians and speech-language pathologists to provide comprehensive care for affected individuals. The results of the current study provide evidence for partial association of PAR index scores and speech abnormalities including improper articulation.

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Authors' contributions
Nada E. Tashkandi: Writing- original draft, visualization, Supervision, Methodology, Formal analysis, Data curation, Conceptualization. Razan AlDosary: Writing- review and editing, Visualization, Investigation, Formal analysis, Data curation. Hissah Zamandar: Writing- review and editing, Validation, Investigation, Data curation, Conceptualization. Misk Alalwan: Writing- Original draft, Visualization, Supervision, Investigation, Formal analysis, Data curation, Conceptualization. Mohannad Alwothainani: Writing- Original draft, Visualization, Supervision, Data curation, Conceptualization, Hissa Aljoaid: Writing- Original draft, Visualization, Data curation, Conceptualization. Duaa Alghazhmri: Writing- Original draft, Visualization, Data curation, Conceptualization, Eman Allam: Writing- Original draft, Visualization, Supervision, Investigation, Formal analysis, Data curation, Conceptualization. Anand Marya- Original draft, Visualization, Project Supervision, Investigation, Formal analysis, Data curation, Conceptualization. Samar M. Adel- Original draft, Visualization, Project Supervision, Investigation, Formal analysis, Data curation, Conceptualization.

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Data availability
The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the declaration of Helsinki and was approved by the Ethical Committee of Riyadh Elm University (SRP/2021/54/463/440).
Written informed consent was obtained from the subjects or their parents before participation in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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