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Research Article

Evaluation of the Association of Oral Stereognosis with Oral Dysfunction and Malocclusion in Children

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Received: February 14, 2025; **Published:** March 03, 2025

Abstract

Background: Stereognosis is the ability to recognize and differentiate the shape of an object using only the sense of touch. Similarly, oral stereognosis refers to an individual's ability to perceive and identify the shape of an object within their mouth without visual input. This study aimed to evaluate the relationship between oral stereognosis and malocclusion in children.

Methods: An observational cross-sectional study was conducted on children aged 8 - 13 years. A total of 60 participants were included, 30 children with SSD (speech sound disorder) group and 30 children with TSD (typical speech development) group. Oral stereognosis was assessed using shape recognition tests, while oral dysfunction was evaluated through clinical examinations. Malocclusion was assessed based on IOTN scale.

Results: Stereognosis scores were positive in all TSD children (100%) but only in (60%) of the SSD group were stereognosis positive and (40%) were negative. On assessing malocclusion, malocclusion was more common in the SSD group (93.3%) compared to TSD group (66.7%). The TSD group had more grade I (33.3%) and grade II (53.3%) malocclusion cases, whereas the SSD group had more grade III (46.7%) and grade IV (6.7%) malocclusion cases. Statistically significant differences were found in IOTN grades (p = 0.05), stereognosis scores (p = 0.006), and their correlation (p = 0.041).

Conclusion: Impaired Oral Stereognosis may contribute to oral dysfunction and is associated with malocclusion in children. Early identification and intervention strategies targeting oral sensory and motor development could aid in improving oral functions and overall dental health.

Keywords: *Oral Stereognosis; Oral Dysfunction; Malocclusion; Oral Motor Function*

Abbreviations

IOTN: Index of Orthodontic Treatment Needs; SSD: Speed Sound Disorders; TSD: Typical Speech Development; MMSE: Mini Mental State Examination

Introduction

The head and neck region encompasses a complex network of structures, such as the jawbones, temporomandibular joint, craniovertebral articulation, teeth, muscles, ligaments, oral soft tissues (including the tongue and lips), organic spaces, vascular system, nervous system, lymphatic system, mucous membranes, and glands. Together, these components form an integrated functional unit.

These elements, which are controlled by the nervous system, interact with the other organ systems and each other to carry out the various tasks. Breathing, sucking, deglutition (swallowing), mastication (chewing), and speech are all functions of the stomatognathic system [1].

The sensory-motor reflex system, which consists of the accompanying motor response and the sensory feedback, is responsible for the many functions performed by the various sections of the human body. The teeth, jawbones, and neuromuscular components of the head and neck area, as well as the functions performed by the orofacial complex, can all be negatively impacted by poor dental occlusion [2].

Therefore, oral sensorimotor development has consistently captured the attention of neonatologists, otolaryngologists, speech and language therapists, and other specialists involved in child development [2].

Stereognosis, variously described as haptic perception or tactile gnosis, is the potential of an individual to recognize and discriminate the form of an object solely based on tactile sensation sans any visual or auditory cue [3].

The word stereognosis comes from the Greek word's "stereo" meaning solid and "gnosis" implying, knowledge [4]. Stereognosis helps in assessing the efficiency of the functioning of the central nervous system [5].

Manual stereognosis involves interpretation of an object placed on an individual's hand based on their ability to perceive and integrate various sensory modalities without any visual aids.

Oral stereognosis, in simple terms, can be explained as the combined ability of the oral structures to identify various geometric shapes. Similar to visual or manual stereognosis, shape recognition by oral structures too requires coordination between the loci collecting sensory inputs and those that distinguish or perceive shape [6]. Oral stereognosis, first described by Berry and Mahood in 1966, refers to the neurosensorial ability of the oral mucous membrane to interpret the form and shape of an object without any visual assistance [8]. This inference of oral perception can be obtained by assessing one's oral stereognostic ability via stereognostic tests, a concept popularized by Grossman [8]. Thus, disturbances of the oral sensory mechanisms and the resultant altered oral motor functions could lead to the development of malocclusions, oral habits like tongue-thrusting, and disturbances in speech, mastication, and occlusal disturbances [7].

TSD refers to the usual progression of speech and language skills in children as they grow. Typical speech development (TSD) requires intact motor, cognitive and linguistic skills and problems in any area can lead to speech impairment. SSD is a neurodevelopmental disorder [33]. SSD children may have difficulty with articulation, phonation, or motor speech performance including childhood apraxia of speech. Speech sound disorders (SSD) rank among the most prevalent neurodevelopmental conditions, affecting an estimated 2% to 13% of children between the ages of 6 and 8 years [33].

The present study was carried out, to explore and gather clinically relevant data on regional sensory perception and to investigate whether altered stereognostic ability could lead to the development of commonly observed malocclusions in mixed dentition.

Materials and Methods

The patients were selected from the regular outpatient department (OPD) of the Department of Paediatrics and Preventive Dentistry at Rishiraj College of Dental Sciences and Research Centre Bhopal, Madhya Pradesh. Ethical approval was obtained from the Institutional ethical committee. The sample size was determined using social sciences 25.0 software (SPSS Inc., Chicago IL). A total of 60 participants were included in the study (30 children with speech sound disorder (SSD) and 30 children with typical speech development (TSD)). This is a prospective cross-sectional observational design study conducted from February 2024 to November 2024.

Inclusion criteria:

1. Children with SSD (Mild SSD grade 1) persisting after the age of 6 years.
2. Healthy children of age 8-13 years of both sexes were selected.
3. Children were selected based on MMSE-Mini-Mental State Examination (19-23: Mild cognitive impairment).
4. The participants with SSD had varying degrees of speech difficulties.

Exclusion criteria:

1. Children previously treated with orthodontic appliances.
2. Children with any mental or physical disability were excluded from study.
3. No moderate or severe intellectual disability, cerebral palsy, or severe autism spectrum disorder.
4. No known Neurodevelopmental disorder.

Thorough oral examination was conducted for all the children falling in the inclusion criteria. Demographic details (name, age, sex, education, geographic location), medical status, number of teeth and type of Dentition was noted for each patient. Intraoral and extraoral examinations were conducted alongside the collection of occlusal records and clinical photographs. The assessment of malocclusion was determined based on the objective need for orthodontic treatment the Index of orthodontic treatment needs (IOTN) [17]. The IOTN-DHC classifies patients into groups based on a defined 5-point scale, with precise cutoff criteria to determine the severity of their condition.

Intraoral sensory-motor function

Stereognosis is not merely the detection of tactile stimuli; it is a far more complex process and involves different other factors and components. Similar to manual stereognosis which finds application in neurology, hand therapy and neuropsychology; oral stereognosis can be beneficial in determining the oral functioning and assess the outcome of oral therapy [9,10]. Berry and Mahood attempted to develop a standardized procedure for oral stereognostic test in terms of size, material, shape and number of test objects [8]. Different approaches and modifications of the form and material of the test items have there on been implemented over the years by various researchers with varied outcomes, without adhering to a standard methodology [11].

Preparation of test pieces

The test pieces were formulated with an inert, non-toxic material. They should preferably be odorless, with no taste or at least, a pleasant one. Various materials have been used in oral stereognostic tests such as metals, acrylic resin, wax, plastic and raw carrot [8,11-16]. While raw carrot seems like a wise choice given its odorless and harmless nature, metal pieces have not been well tolerated by several subjects [5]. The pieces should have rounded edges to avoid any injury to the oral tissues. The thickness of the test pieces should ideally be about 4 mm, and length of 10 mm. In case of using raw carrot as a test piece, stainless steel iron molds may be used for their uniform cutting.

Figure 1: *Different shapes cut out from fresh raw carrots using preformed iron molds.*

Oral stereognostic tests

All the selected patient was made to sit comfortably on dental chair. Procedure was explained to children in local language to reduce anxiety. In this study, a set of six different shapes were used (star, drop shape, circle, diamond, heart, etc.) as described in the picture above (Figure 1). Participants were blind folded in order to reduce visual bias. The figure was placed on the dorsum of the tongue by the examiner using a tweezer for easy placement (Figure 2). The participant was then asked to close the mouth and "feel the shape of the figure". The figure was removed after 10 seconds, and the participant was asked to point to pictures of the figures to determine which picture matched the figure in the mouth. A sheet was shown to the subjects illustrating the shapes of the test pieces in their normal and enlarged sizes in order to facilitate the recognition after the test (Figure 3). A minimum of three shapes correctly identified out of the six offered to each child was considered as an indicator of the adequate stereognostic ability of that particular child. The maximum score was 6 when all the figures were correctly identified. Typically developing children (TSD) of age 8 - 9 years is expected to perform very well on this assessment.

Figure 2: *Placement of the shape on the dorsum of the tongue with eyes blind folded.*

Figure 3: *Identification of the shape from the chart.*

Results

The data analysis was done using the statistical package of social sciences 25.0 software (SPSS Inc., Chicago IL). Results were statistically analyzed by tests including the Chi-square test, and Binary logistic regression analysis was used to evaluate the potential association between malocclusion and stereognosis. A 'p' value of 0.05 was considered for statistical significance.

Out of these 60 children, 36 (60.0%) belonged to the age group of 8-10 years and 24 (40.0%) were in the age group of 11-13 years.

Children with SSD and TSD had their IOTN grades compared in this study. The TSD group had a higher prevalence of grade I (No malocclusion) (33.3%) than the SSD group (6.7%). Compared to the SSD group (40%) grade II is more common in the TSD group (53.3%). The SSD group has a higher prevalence of grade III (46.7%) than the TSD group (13.3%). There is only grade IV (6.7%) in the SSD category. There is statistically significant difference between the two groups, as indicated by the p-value of 0.05 (Table 1 and figure 4).

IOTN grades	SSD Group	TSD Group	p-value
Grade I	2 (6.7%)	10 (33.3%)	0.05*
Grade II	12 (40.0%)	16 (53.4%)	
Grade III	14 (46.6%)	4 (13.3%)	
Grade IV	2 (6.7%)	0 (0.0%)	
Total	30 (100%)	30 (100%)	

Table 1: *Comparison of frequency distribution of IOTN grades among children with SSD and TSD.*

**Statistically significant.*

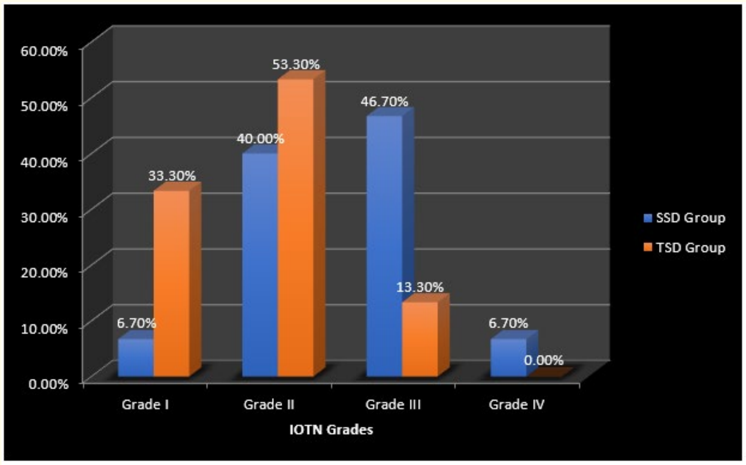

Figure 4: *Comparison of frequency distribution of IOTN grades among children with SSD and TSD.*

A comparison of the stereognosis scores for the SSD group and the TSD group is shown in table 2 and figure 5. Positive scores were present in 60.0% of the SSD group and 100.0% of the TSD group. 40.0% of the SSD group had negative scores, while 0% of the TSD group did not. A statistically significant difference between the groups is indicated by the p-value of 0.006.

Stereognosis score	SSD Group	TSD Group	p-value
Positive	18 (60.0%)	30 (100.0%)	0.006*
Negative	12 (40.0%)	0 (0.0%)	
Total	30 (100%)	30 (100%)	

Table 2: *Comparison of frequency distribution of stereognosis score among children with SSD and TSD.*

**Statistically significant.*

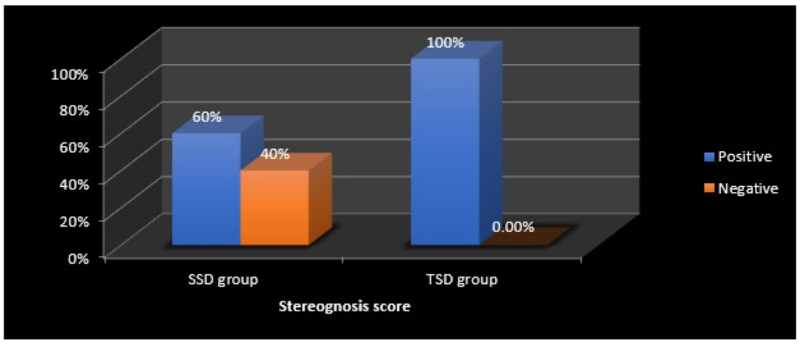

Figure 5: *Comparison of frequency distribution of stereognosis score among children with SSD and TSD.*

The SSD group and TSD group's IOTN (Index of orthodontic treatment need) grades and stereognosis scores are contrasted in this table. While negative stereognosis scores are found in all grades except grade I, positive stereognosis scores are mostly found in grades II and III in the SSD group. In the TSD group, all participants with positive stereognosis scores are found in grades I, II, and III. There are no negative stereognosis scores found in children's with TSD. There is statistically significant correlation between IOTN grades and stereognosis scores, as indicated by the p-value of 0.041 (Table 3 and figure 6).

IOTN grades	Stereognosis			
	SSD Group		TSD Group	
	Positive	Negative	Positive	Negative
Grade I	0 (0.0%)	2 (6.7%)	10 (33.3%)	0 (0.0%)
Grade II	8 (26.7%)	4 (13.3%)	16 (53.3%)	0 (0.0%)
Grade III	10 (33.3%	4 (13.3%)	4 (13.3%)	0 (0.0%)
Grade IV	0 (0.0%)	2 (6.7%)	0 (0.0%)	0 (0.0%)
Total	18 (60.0%)	12 (40.0%)	30 (100%)	0 (0.0%)
p-value	0.041*			

Table 3: *Association between IOTN grades and stereognosis among children with SSD and TSD.*

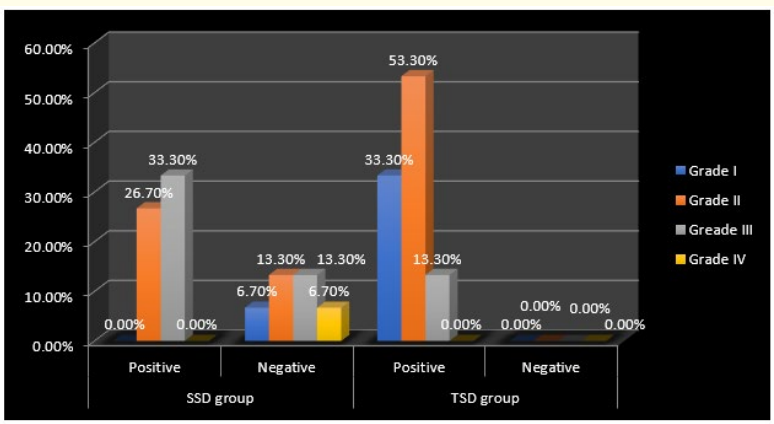

Figure 6: *Association between IOTN grades and stereognosis among children with SSD and TSD.*

The two groups have comparable mean ages (10.7 and 10.4). Both groups had the same sex ratio (14 boys: 16 girls).

The TSD group had a higher rate of no malocclusion (33.3%) than the SSD group (6.7%). Compared to the TSD group (66.7%), the SSD group experienced malocclusion more frequently (93.3%). The P-value of 0.006 was statistically significant (Table 4).

Variables	Children with SSD	Children with TSD	p- value
Demographic information			
Mean age	10.7 ± 1.66	10.4 ± 1.29	
Sex (M:F)	14:16	14:16	
Malocclusion n (%)			
No malocclusion	2 (6.7%)	10 (33.3%)	0.006*
Malocclusion	28 (93.3%)	20 (66.7%)	

Table 4: *Comparison of demographic and malocclusion between SSD and TDS groups.*

**Statistically significant.*

The relationship between malocclusion and stereognosis scores is shown by the regression analysis. With a statistically significant p-value of 0.04, people with positive stereognosis in this instance are 3.326 times more likely to experience the malocclusion than people with negative stereognosis (Table 5).

Variables	Coefficient B	p-value	Odds Ratio (Exp (B))	95% C.I. for EXP (B)	
				Lower	Upper
Stereognosis (Positive/ Negative)	1.202	0.04*	3.326	1.042	10.617

Table 5: *Logistic regression model for malocclusion with stereognosis.*

**Statistically significant.*

Discussion

The motor functions of the lips, cheeks, jaws, and tongue play a vital role in the development and maturation of orofacial structures, which, in turn, influence a child's feeding process and speech development. Most of the essential processes for refining oral functions take place during early childhood, making the sensorimotor and cognitive experiences from this period foundational for the development of more advanced sensorimotor functions [18]. The progressive advancement of higher brain functions is referred to as encephalization, which is closely linked to both local sensory maturation and the motor development of the head and neck [19]. However, this relationship can be disrupted by dentofacial deformities (DFD) and malocclusions associated with skeletal disorders, which result in disharmony between the maxilla and mandible. Since the jawbones form the structural foundation of the dental arches, any alterations in their growth pattern and direction can affect occlusal relationships and functions, potentially leading to malocclusion and/or functional impairments [20]. Therefore, this study aimed to explore the possible association between altered sensory perception and malocclusion during the mixed dentition phase.

The evaluation of oral stereognosis in children involves assessing their ability to recognize and discriminate various shapes and textures using only their oral sensory receptors. Children with malocclusion often demonstrate a reduced ability to accurately identify these stimuli, indicating a disruption in the sensory processing pathways. This impaired function can be attributed to altered mechanoreceptor activation and compromised neural feedback mechanisms. Such evaluations provide insight into the degree of sensory dysfunction associated with malocclusion.

Children with malocclusion may experience challenges in activities requiring fine oral-motor control, such as mastication and speech articulation. Reduced stereognostic ability could also hinder their adaptive response to oral sensory stimuli, potentially impacting their nutritional intake and overall oral health. Early orthodontic intervention may thus play a dual role in correcting structural abnormalities and enhancing sensory-motor integration.

To ensure that participants had an intelligence level suitable for the selected age group, a mini-mental state test was conducted prior to their inclusion in the study. Malocclusion grading in this study was based on the dental health component of the index of orthodontic treatment need (IOTN), originally described by Brook and Shaw and later modified by Richmond [17,21,22]. This index evaluates malocclusion by assessing the impact of various occlusal traits on an individual's dental health and perceived aesthetic concerns. However, in this study, the aesthetic component was excluded, as the participants were in the early and middle mixed dentition stages, during which aesthetic evaluation is challenging due to the natural transitional changes occurring at this age. The IOTN has been widely used to assess malocclusion in different populations, and its reproducibility has been validated, demonstrating substantial agreement within the age group analyzed in this study [23,24].

Among the 60 children examined, 60.0% belonged to the age group of 7 - 10 years. And 40.0% were in the age group of 11 - 14 years. The majority of children in the present study population belonged to SSD group that experienced malocclusion more frequently (93.3%). or the group with significant orthodontic problems and require orthodontic treatment at this point. When the association between IOTN grades and age of the children are compared, a significant association could not be drawn which can be inferred as the lack of significant difference in the incidence of malocclusion in both the age groups. This may be because both age groups included in the study are in the mixed dentition stage, making the time frame too limited for any substantial differences to emerge. However, a significant variation was observed in the shape identification scores between the two age groups, which could be attributed to the enhanced stereognostic ability in older children. These findings align with the study by Shivakumar., *et al.* [25] who examined the prevalence of malocclusion and orthodontic treatment needs among middle and high school students, reporting that 80.1% of schoolchildren had either no malocclusion or only minor cases requiring minimal or no treatment.

55.1% of the subjects in the present study were boys and 44.9% were girls. When their IOTN grades were compared with their gender, there was no association noted between the IOTN grades and gender. This is in correlation with the study conducted by Laganà., *et al*. [26] who used IOTN to grade malocclusion and found that no significant differences existed between the genders and prevalence of malocclusion.

When comparing the total percentage of correct shape identification across different IOTN grades, a statistically significant decline is observed between IOTN grades I and IV. This reduction is evident for all six shapes used in the study, regardless of their complexity or familiarity. These findings suggest a variation in oral stereognostic ability between individuals with and without malocclusion, based on the criteria used in this study.

Similar to the findings of the earlier authors in this study also a significant association could not be drawn between the gender of the children and their stereognostic ability [27-29]. There were similar proportions of both boys and girls among the positive responders.

Koczorowski., *et al*. [30] conducted a study on patients with anterior open bite and found that their stereognostic ability was compromised. They also observed a significant decline in this ability following the application of a 5% topical anaesthetic gel on the tongue. Based on these findings, they concluded that the tongue plays a key role in determining oral stereognostic ability. In individuals with an open bite, improper tongue positioning and reduced motor activity contribute to this impairment. Similarly, Premkumar., *et al*. [19] investigated the stereognostic ability of children aged 12 to 17 years with and without anterior open bite. Their study revealed that children and adolescents with anterior open bite and tongue thrust had significantly lower shape and texture identification abilities compared to those with normal occlusion. Although the present study did not statistically assess anterior open bite specifically, a decline in stereognostic ability was observed in children with this condition.

Studies have shown that individuals with cleft palate exhibit significantly lower oral stereognostic ability compared to those without the condition [31]. However, Grasso and Catalanatto reported contradictory findings, concluding that palatal coverage does not appear to influence stereognostic ability [32]. In this study, a single participant with an untreated cleft palate successfully identified all five stereognostic forms within the allotted 30-second timeframe. While no statistical significance could be drawn from this result, it suggests a potential indication of the tongue's crucial role-particularly the tip-over the palate in perceiving oral sensations. This aligns with the present study's observation that an individual with a tongue tie and restricted tongue mobility was only able to identify two out of the five shapes, leading to their classification as having reduced stereognostic ability based on the study's criteria. In addition to malocclusion, oral stereognostic deficits have been associated with broader oral dysfunctions. These include difficulties in speech articulation, where precise tongue and lip movements rely on accurate sensory input, and issues in mastication, where inefficient chewing can result from reduced sensory discrimination. Such dysfunctions underline the importance of comprehensive oral evaluations that consider both structural and sensory factors.

However, oral stereognosis is influenced by various factors beyond occlusion, such as cognitive development, and individual exposure to sensory stimuli. These factors could have contributed to the observed variations and must be considered in future research. Additionally, longitudinal studies are needed to determine whether malocclusion directly causes impaired oral stereognosis or if both conditions share common developmental risk factors.

Conclusion

This study highlights the association between malocclusion and reduced oral stereognostic ability in children, emphasizing the importance of addressing sensory and structural aspects in oral healthcare. The findings of this study indicate that children classified as having malocclusion, based on the applied index and within the selected age group, exhibit altered oral sensory perception. Given that the sensory and motor aspects of the orofacial region are inherently interconnected in both structure and function, the relationship between orofacial growth, development, and sensory maturation should not be disregarded. Further well-structured research on groups with malocclusion is necessary to provide insight into potential evidence-based correlations in this field. By understanding and managing these interconnected factors, clinicians can optimize functional outcomes and improve the quality of life for affected children.

Conflict of Interest

None.

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