Original Article

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Dentistry Section

The Prevalence of Malocclusion among Six- and Nine-year-old School-going Children of Visakhapatnam: A Cross-sectional Study

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ABSTRACT

Introduction: Malocclusion profoundly impacts a child's emotional well-being and affects an individual's quality of life. Early identification improves the chances of organising preventive and interceptive treatment to limit the intensity of developmental aberrations. The data for malocclusion among children of Visakhapatnam is lacking.

Aim: To study and evaluate the prevalence of malocclusion and ascertain gender dimorphism among six and nine-year-old school-going children of Visakhapatnam

Materials and Methods: A cross-sectional, double-stage sample study was conducted among 616 school-going children of Visakhapatnam, Andhra Pradesh, India, by a single calibrated examiner using a modified Index for Preventive and Interceptive Orthodontic Needs (IPION). IBM Statistical Package for the Social Sciences (SPSS), version 25.0, was used to analyse data and Pearson's Chi-square test to elicit gender differences in the prevalence of malocclusion traits.

Results: Prevalence among six-year-old children: interproximal caries-38.4%, premature tooth loss-10.1%, supernumerary teeth-0.3%, upper molar rotation-0.3%, lower molar tipping-2%, anterior crossbite-2.7%, posterior crossbite-0.7%, overjet more than 3 mm-5.1%, overbite more than 2/3rd-8.4%, open bite-2%, incompetent lips-13.8%. Prevalence among nine-year-old children: interproximal caries-49.5%, premature tooth loss-8.8%, active frenum-2.8%, supernumerary teeth-0.6%, diastema-3.4%, upper molar rotation-2.2%, lower molar tipping-5%, impended eruption of first permanent molar-1.3%, overjet more than 3 mm-11%, overbite more than 2/3rd-12.5%, open bite-2.2%, anterior crossbite-8.2%, posterior crossbite tendency-3.1%, Class I-75.6%, Class II-18.8%, Class III (functional shift)-0.6%, Class III (no functional shift)-3.76%, incompetent lips-16.3%.

Conclusion: Children from both cohorts demonstrated malocclusion traits. The nine-year-old group had greater prevalence for all components examined except premature tooth loss. No statistically significant gender dimorphism was found in both cohorts.

Keywords: Diastema, Open bite, Overbite, Supernumerary, Tooth loss

INTRODUCTION

According to Edward H Angle, in studying a case of malocclusion, give no thought to the methods of treatment or appliances until the case shall have been classified and if, all peculiarities and variations from the normal in type, occlusion, and facial lines have been thoroughly comprehended, then the requirements and proper plan of treatment become apparent [1].

Early orthodontic treatment is conceivably easy to perform, consumes less time, and is pocket friendly. Such interceptive measures may not always lead to a final result but do contribute to a considerable lessening of further orthodontic treatment need in children [2]. The clinical guidelines by the American Academy of Paediatric Dentistry (AAPD) also draw attention to the fact that 'early diagnosis and successful treatment of the developing malocclusion can have both short-term and long-term benefits along with functional harmony and dentofacial aesthetics' [3].

Globally, malocclusion ranges between 39-98% [4-7]. India has an estimated 20-43% of children [4] demonstrating malocclusion and 31.4% [7] of them are from the southern macro-region. Children aged 4-6 years particularly, had a high prevalence of overjet and overbite (81.6% and 84.5%, respectively) [5], with a majority of them showing deviations like lower anterior crowding, crossbites, open bite, and pseudo-Class III during the early mixed dentition [6].

Establishing credible evaluation methods for malocclusion is a difficult and daunting task [8]. Though several indices have been developed to organise malocclusion into relevant groups, none of them ensure an all-inclusive criterion [9]. Some of these indices like the Dental Aesthetic Index (DAI), Index of Orthodontic Treatment Need (IOTN), and Index of Complexity Outcome and Need (ICON) include a subjective method [9] to evaluate malocclusion, but studies [10,11] have shown that parents and patients cannot efficiently assess such subjective traits at an early age and may not comprehend their long-term implications. Trained clinicians can diagnose these problems and intercept or prevent most of them.

The IPION is a valid, quick, and easy-to-use tool that permits early detection of malocclusion with minimal subjectivity [12-14]. It is the sole index that records malocclusion traits specifically in children aged six and nine years [12]. These cohorts are important in dentofacial development because the age of six years marks the beginning of mixed dentition and the age of nine years heralds the eruption of the canine-premolar group of teeth. So, these age groups benefit the most from early orthodontic interventions [15].

There has been a particularly growing interest and an increasing demand for orthodontic services [15]. Though studies [3-5] have reported malocclusion among Indian children using various indices, such data is lacking in this geographic region for children in mixed dentition. Therefore, the present study was undertaken to ascertain malocclusion among six and nine-year-old school children using IPION. The null hypothesis was that school-going children aged six and nine years did not have malocclusion traits and the alternate hypothesis was that these children did demonstrate such characteristics. Hence, the present study aimed to study the prevalence of malocclusion among school-going children of Visakhapatnam, Andhra Pradesh, India, aged six and nine years and also, to determine gender dimorphism for the examined malocclusion traits for both age groups.

MATERIALS AND METHODS

A cross-sectional double-stage sample study was conducted among six and nine-year-old school-going children of Visakhapatnam, Andhra Pradesh, India, for 15 months (December 2018 to February 2020). The study was approved by the Institutional Ethical Committee.

Sample size calculation: The sample size was calculated based on the formula (Daniel 1999) $n=Z^2P(1-P)/d^2$ {confidence level (Z)=95%, expected prevalence (P)=0.05, and, the margin of (d)=5%} [16]. As there was no previously reported data regarding malocclusion among the target population, the probability was set at 50% and the minimum sample size of 384 was arrived at. Using the two-stage stratified random sampling method, 24 schools representing all the constituency areas of Visakhapatnam were selected in the first stage. In stage two, children aged six years (5.9-7 years) and nine years (8.6-9.6 years) [8] were chosen from the selected schools. Permission and informed consent were obtained from the concerned school authorities and parents. Following universal precautions and infection control procedures based on the World Health Organisation (WHO) Oral Survey Basic Methods [17] and abiding by the World Medical Association (WMA) Declaration of Helsinki, a single, calibrated examiner conducted the study.

Inclusion criteria: Children aged six and nine years enrolled in the schools of Visakhapatnam were included in the study.

Exclusion criteria:

- Children of ages other than six and nine years enrolled in the schools of Visakhapatnam.
- From the age groups of six and nine years, children who were not willing to participate in the study, children who were undergoing orthodontic treatment at the time of the study, and children with congenital craniofacial abnormalities, were excluded from the study.

Study Procedure

The IPION screens children in their mixed dentition and determines the need for preventive and interceptive orthodontic treatment need [12-14,18]. The components examined for both cohorts are listed in [Table/Fig-1]. Children were called out based on the roll call of their respective classes and were made to rinse their mouths before the examination. They were examined at their school premises in well-lit classrooms or corridors [Table/Fig-2,3] using a mouth mirror and an explorer (Type 3 examination) [17].

Component	Six-year-old children	Nine-year-old children
Primary	Interproximal caries Early loss of primary teeth	
Anterior	Supernumerary teeth	Supernumerary teeth Active frenum Diastema
Posterior	Upper molar rotation Lower molar tipping	Upper molar rotation Lower molar tipping Impended eruption of fpm
Occlusal	Overjet Overbite Open bite Anterior crossbite Posterior crossbite	Overjet Overbite Open bite Anterior crossbite Posterior crossbite Anteroposterior molar relation
Soft tissue	Lip competency	

[Table/Fig-1]: Components examined based on IPION.
fpm: First permanent molar

Originally, Coetzee CE and de Muelenaere KR used a custom-built plastic IPION ruler for measuring the malocclusion traits [13]. In the present study, while all components were examined and evaluated based on the IPION criteria, two of them were modified (evaluation of upper molar rotation and lower molar tipping) for ease of clinical application. Following the premature loss of a maxillary primary molar, rotation of the upper permanent molar from the same quadrant was ascertained when an imaginary line extending between the distobuccal cusp and mesiolingual cusp of the maxillary first permanent molar crossed distal to the contact point of contralateral primary first and second molars. Disposable wooden spatulas [19] were used to create this imaginary line in the maxillary arch of the child's oral cavity [Table/Fig-4]. Following premature loss of a mandibular primary molar, tipping of the lower first permanent molar of the same quadrant was evaluated. A metal scale was modified to measure an acute angulation of 15° [Table/Fig-5]. The metal scales were used as: a) They could be easily/accurately modified from a conventional metal scale to reflect the 15° inclination; b) They could be easily cleaned and sterilised after each survey day; c) Would not break or have wear-and-tear during the long survey period of the current study. This scale was held parallel to the gingival margins of the mandibular teeth in that quadrant and when the long axis of the mandibular first permanent molar was inclined more than 15° mesially, it was recorded as a tipped mandibular first permanent molar [Table/Fig-6]. After examination, scores were recorded on a separate datasheet for each child. At the end of each survey day, the final score for each child was calculated and the data was transferred to separate Excel sheets for both cohorts (Microsoft® excel® 2019 MSO, version 2211). The sample selection and distribution has been given in [Table/Fig-7].

[Table/Fig-2]: Armamentarium.

[Table/Fig-3]: Clinical examination.

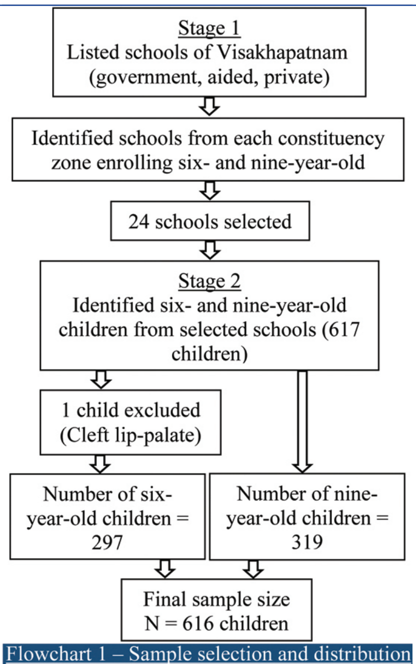
STATISTICAL ANALYSIS

Once the survey was completed, data was analysed using IBM SPSS. Armonk, NY: IBM Corp; 2017 version 25.0, for computation of prevalence rate of the recorded malocclusion traits in both age groups. Pearson's Chi-square test (significant if $p<0.05$) was used to evaluate gender differences. Additionally, Mann-Whitney U test was used to compare means of the variables. Wilcoxon W-test and z-test were used to compare the group means (significant, if $p<0.05$). All applicable Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were adhered to [20].

[Table/Fig-4]: Assessing upper molar rotation using a disposable wooden spatula.

[Table/Fig-5]: Modified metal scales.

[Table/Fig-6]: Assessing lower molar tipping using a modified metal scale.



[Table/Fig-7]: Sample selection and distribution.

RESULTS

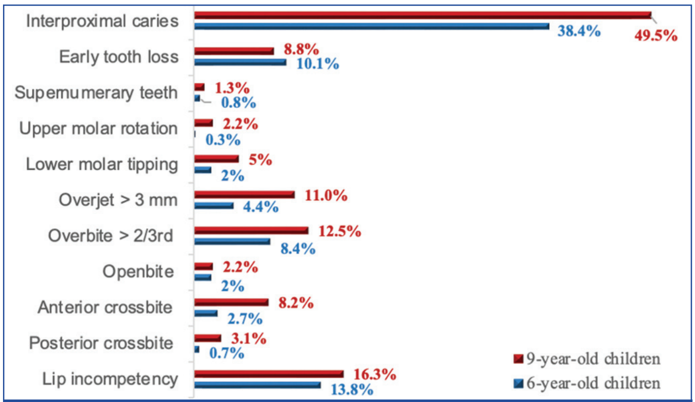
A total of 616 children {297 children from the six-year-old group (male-168 children, female-129 children) and 319 children from the nine-year-old group (male-160 children, female-159 children)-[Table/Fig-7]} were evaluated during this study. Children from both cohorts demonstrated malocclusion and therefore, the null hypothesis was rejected. The study results are tabulated in [Table/Fig-8,9]. The observations from [Table/Fig-8] reflect that the examined six-year-old children demonstrated a particular prevalence for the primary component (interproximal caries-38.4%, and early tooth loss-10.1%) and the soft tissue components of IPION (lip incompetency-13.9%) along with overjet (5.1%) and overbite (8.5%). Supernumerary teeth (0.3% and crossbites (anterior crossbite-2.7% and posterior crossbite-0.7%) were also noted. The observations from [Table/Fig-9] show that approximately half of the examined nine-year-old children (49.5%) had interproximal caries, 7.2% had an anterior crossbite, 3.1% showed a posterior crossbite and 1.3% of them had impended eruption of first permanent molar. The older group of children also demonstrated an increased prevalence for all the examined components except for early tooth loss. [Table/Fig-10] shows the comparative prevalence of malocclusion traits between the six and nine-year-old. No statistically significant gender dimorphism was seen in both cohorts (p-value >0.05).

Malocclusion trait	Girls	Boys	Total	χ^2	p-value
Interproximal caries	50 (16.8%)	64 (21.5%)	114 (38.4%)	25.635	0.081
Early tooth loss	12 (4.04%)	18 (6.06%)	30 (10.1%)	3.122	0.538
Supernumerary teeth	1 (0.3%)	0	1 (0.3%)	1.307	0.253
Upper molar rotation	1 (0.3%)	0	1 (0.3%)	1.307	0.253
Lower molar tipping	2 (0.6%)	4 (1.3%)	6 (2%)	0.593	0.743
Anterior crossbite	2 (0.7%)	6 (2%)	8 (2.7%)	2.358	0.308
Posterior crossbite	1 (0.3%)	1 (0.3%)	2 (0.7%)	2.070	0.355
Overjet >3 mm	6 (2%)	9 (3%)	15 (5.1%)	3.841	0.279
Overbite >2/3rd	9 (3.1%)	16 (5.43%)	25 (8.5%)	1.701	0.427
Open bite	4 (1.4%)	2 (0.6%)	6 (2%)	4.059	0.255
Incompetent lips	16 (5.4%)	25 (8.4%)	41 (13.9%)	3.861	0.145

[Table/Fig-8]: Malocclusion traits in six-year-old children (N=297; Girls=129; Boys=168).
X^2-Pearson Chi-square value. Significant if p<0.05

Malocclusion traits	Girls	Boys	Total	χ^2	p-value
Interproximal caries	81 (25.3%)	77 (24.1%)	158 (49.5%)	16.614	0.481
Early tooth loss	17 (5.3%)	11 (3.4%)	28 (8.8%)	8.590	0.283
Active frenum	5 (1.6%)	4 (1.2%)	9 (2.8%)	0.121	0.728
Supernumerary teeth	0	2 (0.6%)	2 (0.6%)	2.000	0.157
Diastema	3 (0.9%)	8 (2.5%)	11 (3.4%)	2.322	0.128
Upper molar rotation	4 (1.4%)	3 (0.9%)	7 (2.2%)	1.010	0.604
Lower molar tipping	7 (2.2%)	9 (2.8%)	16 (5%)	7.000	0.13
Anterior crossbite	11 (2.5%)	15 (4.7%)	26 (7.2%)	3.599	0.308
Posterior crossbite	4 (1.2%)	6 (2%)	10 (3.1%)	7.000	0.072
Overjet >3 mm	20 (6.3%)	15 (4.6%)	35 (11%)	2.105	0.716
Overbite >2/3rd	20 (6.3%)	20 (6.3%)	40 (12.6%)	0.144	0.931
Open bite	5 (1.5%)	2 (0.6%)	7 (2.13%)	2.382	0.497
AP molar relation Class-I Class-II Class-III • functional shift • no functional shift	 117 (36.7%) 33 (10.3%) 1 (0.3%) 6 (1.8%) 2 (0.63%)	 124 (38.9%) 27 (8.46%) 1 (0.3%) 6 (1.8%) 2 (0.63%)	 241 (75.6%) 60 (18.8%) 2 (0.6%) 12 (3.76%) 4 (1.25%)	0.788	0.675
Flush terminal plane Incompetent lips	28 (8.7%)	24 (7.5%)	42 (16.2%)	4.091	0.129

[Table/Fig-9]: Malocclusion traits in nine-year-old children (N=319; Girls=159; Boys=160).
X^2-Pearson's Chi-Square value. Significant if p<0.05



[Table/Fig-10]: Comparison of malocclusion trait prevelance (%) between six-year-old and nine-year-old children.

DISCUSSION

Early identification of malocclusion improves the chances of organising preventive and interceptive treatments [7]. Recording metric parameters during mixed dentition stages aids to differentiate between conditions that self-correct and a few others that may progress into serious functional and physical handicaps [21]. Characteristics like overjet, overbite, and crossbites can be rectified with simple methods and reduce the need for further treatment [15].

Interproximal caries and premature loss of primary teeth were evaluated in both cohorts. Proximal caries compromises arch circumference and may jeopardise the space available for succedaneous teeth [3,11,22]. Chewing efficiency is directly proportional to the number of occlusal contact areas and influences masticatory performance. The ensuing deviations in muscular activity lead to variations in arch growth and verticle jaw dimensions [22]. Similarly, early loss of one or more primary teeth results in an estimated three-fold increase in orthodontic treatment need [1].

The current study found that the primary mandibular first molar most frequently demonstrated interproximal caries in both cohorts, similar to the findings by Rapeepattana S et al., and Tungaraza JP et al., [14,18]. The tooth lost early was the primary maxillary first molar in the six-year-old group and the primary mandibular second molar in the nine-year-old group. Karaiskos N et al., [23] reported similar results for the six-year-old group and in the nine-year-old group, the results match the findings of studies from Philadelphia, Thailand, and Tanzania [Table/Fig-11] [12,14,15,18,23,24].

Approximately, 1/3rd of the primary dentition with a supernumerary tooth demonstrate one such tooth in their permanent dentition too and in about 2% of the population, maxillary incisors are impacted or ectopically erupted due to a supernumerary tooth [3]. Such teeth may also hinder normal eruption of the succedaneous teeth, cause over-retention of deciduous teeth, root deflection, tooth displacement, diastema, aberrant root resorption, or cystic lesions. The findings of the current study [Table/Fig-12] are at par with the global prevalence of 0.3-0.8% in the primary dentition and 0.52% to 2% in the mixed dentition [6,12,14,15,25-28].

Author	Country and sample size	Age (and no. of children)	Interproximal caries (%) and commonly affected tooth		Early loss (%) and the commonly lost tooth	
Haider Z 2013 [12]	Philadelphia (N=87)	6 yrs (n=32)	E-40.62%	E	D-6.25%	Lower D
		9 yrs (n=55)	D-61.1%	D	LE-9.09%	Lower E
Karaiskos N et al., 2018 [23]	Canada (N=395)	6 yrs (n=201)	30.4%	E	11.9%	D
		9 yrs (n=197)	20.6%	E	29.4%	C
Ibrahim MM 2018 [24]	Egypt (N=97)	Girls-55 Boys-42	6 yrs 68%	-	40%	-
			9 yrs 68.2%		13.6%	
Rauten AM et al., 2019 [15]	Romania (N=147)	6 yrs (n=69)	24%	E	17.39%	D
		9 yrs (n=78)	16.66%	E	23.07%	C
Rapeepattana S et al., 2019 [14]	Thailand	8-9 yrs (N=202)	D-77.8%	D	24.8%	E
Tungaraza JP et al., 2019 [18]	Tanzania (N=667)	6 yrs (n=317)	35.1%	Lower D	10.7%	Lower E
		9 yrs (n=350)	20.20%	Lower D	4.9%	Lower E
Present study	India (N=616)	6 yrs (n=297)	38.4%	Lower D	10.1%	Upper D
		9 yrs (n=319)	49.5%	Lower D	8.8%	Lower E

[Table/Fig-11]: Anterior component of IPION-Comparison with age-matched studies [12,14,15,18,23,24].
-= Not reported; C=Primary canine; D=Primary first molar; E=Primary second molar; LE=Lower primary second molar

Author and country	Age (Sample size)	Supernumerary teeth (%)	Diastema (%)			Active frenum (%)
Babler-Zeltmann S et al., 1998, Sweden [25]	8.5-9.5 y (N=1020)	0.2%	16.4%	Girls-6.8%	Boys-9.6%	-
Singh A et al., 2011, India [26]	12 y (N=927)	-	9.8%	Girls-14.2%	Boys-5.9%	-
Kumar DA et al., 2012, India [27]	7-18 y (N=883)	-	7.2%	Girls-9.6%	Boys-6.5%	-
Reddy ER et al., 2013, India [6]	6-10 y (N=2135)	-	7.2%			-
Haider Z, 2013 Philadelphia [12]	9 y (N=87)	1.82%	38.18%			43.64%
Siddegowda R and Satish RM 2014, India [28]	10-16 y (N=9505)	-	6.2%	Girls-6.3%	Boys-6%	-
Rapeepattana S et al., 2019, Thailand [14]	8-9 y (N=202)	0.5%	12.2%			8.9%
Rauten AM et al., 2019, Romania [15]	9 y (N=147)	-	-			2.56%
Present study India	9 y (N=319)	0.6%	3.4%	Girls-0.9%	Boys-2.5%	2.8%

[Table/Fig-12]: Anterior component of IPION-Comparison with age-matched studies [6,12,14,15,25-28].
(-= Not reported)

A diastema of 2 mm is a common finding in children (26%) and shows spontaneous closure. But a diastema of more than 2 mm may not close spontaneously and is seen in about 6% of adolescents and adults [1,3] with a global prevalence ranging from 12.2-38.18% [12,14,25]. The current study found it to be 3.4% in the nine-year-old group (girls-0.9%, boys-2.5%). This greater prevalence among boys as compared to girls is in agreement with Babler-Zeltmann S et al., but in contradiction to studies in the Indian population [25-27]. A thick, abnormal labial frenum could be an aetiological factor for midline diastema. The prevalence of an active labial frenum in the nine-year-old children of the current study are similar to the findings by Rauten AM et al., [15].

Literature mentions several methods to assess upper molar rotation like plaster models [29], photocopies of plaster models [29], and panoramic and lateral cephalograms [30]. For lower molar tipping, techniques like plaster models [29], and panoramic radiographs [30] have been used. In the present study, a novel modification was used for an easier clinical appraisal (detailed in methodology). The nine-year-old children demonstrated an increased prevalence for both these parameters. This could be due to the time elapsed after premature loss and also the lack of space management interventions. Furthermore, the effects of premature loss of primary second molars could be different at the ages of 6, 7, and 8 years [31]. Haider Z reported an upper molar rotation of 7.41% and lower molar tipping of 9.26% in nine-year-old children [12]. The higher prevalence reported by Rapeepattana S et al., (upper molar rotation-13.7%, lower molar tipping-23.1%) could be due to the greater incidence of interproximal caries (91.6%) and premature loss of primary second molar (24.5%) in that study population [14].

Impended eruption of first permanent molars was seen in 1.3% of nine-year-old children of the current study. Babler-Zeltmann S et al., reported delayed eruption of the first permanent molar in 1.4% of nine-year-old children [25], while Arathi R et al., reported delayed eruption of all first permanent molars in a nine-year-old female child [32]. Crossbites may alter skeletal growth pattern, compromise arch perimeter, damage periodontal tissues, and lead to temporomandibular disorder or pseudo-Class III. As age increases, differential diagnosis becomes difficult and treatment outcomes are less favourable [31]. Early detection and management are vital because lesser than 10% of functional crossbites are self-correcting [3]. Globally, anterior crossbites range from 2.2-30.7% [13,15,18,24,25,33] and posterior crossbites from 4.3-17% in children aged 6-10 years [13,14,34]. The higher prevalence of crossbites observed in older group children was in agreement with studies in this region of India [4,5] and reiterates the importance of early identification of any developing malocclusion [Table/Fig-13] [5,6,8,14,15,18,24,25,33-35].

An overjet of more than 8 mm increases the prevalence of traumatic dental injuries by about 40% [3]. While digit sucking and pacifier use increase the chances of anterior open bite [3,31], a deep overbite may cause eustachian tube dysfunction [36]. Keski-Nisula K et al., attributed an anterior open bite of 4.6% among children aged 4-7.8 years to the significantly greater use of pacifiers [33]. Olatokunbo da Costa O et al., found an overjet of 44.6% among six and 12-year-old children and attributed it to the greater incidence of digit sucking among those children [34]. The global prevalence of overjet and the relation of anterior teeth in the verticle direction (overbite and open bite) differs based on the demographics of the region [Table/Fig-14] [4,5,8,14,18,24,26,33-35,37]. The findings from the current study are comparable to results by Ibrahim MM in age-matched children [24].

An ideal occlusion during childhood results in an ideal occlusion during adulthood. Class I interdigitation is the most desirable occlusion with normal skeletal, soft tissue profile and favorable sagittal relationship. Class II demonstrates a convex profile and Class III shows excessive mandibular growth. Some features which can influence the dental arch status in mid-adolescent stage can be easily recognised during transitional dentition [1]. Results from the current study and other studies for anteroposterior molar relation are listed in [Table/Fig-15] [5,6,15,24,27,37].

Equilibrium between intraoral and extraoral muscles influences the developing dentition and affects tooth eruption. Incompetent lips predispose the maxillary incisors to traumatic dental injury [31] and alter the jaw posture at rest, leading to variation in lip-tongue equilibrium and altered occlusal forces [11]. The findings of the present study for the prevalence of lip incompetency [Table/Fig-16] are in agreement with other studies among 6 to 11-year-old children [14,18,34]. The higher prevalence (43.6%) found among 6- and 12-year-old Nigerian children [34] could be due to the greater incidence of deleterious oral habits found in them.

The findings of the present study highlight the need to evaluate children in their early stages of growth and follow them till the completion of growth. This enables the application of preventive and interceptive methods to avert or minimise any developing

Author and sample size	Country	Age group	Crossbite (%)	
			Anterior	Posterior
Hill PA, 1992 (N=268) [8]	Scotland	9 y	7.5%	6.3%
Babler-Zeltmann S et al., 1998 (N=1020) [25]	Germany	8.5-9.5 y	5.1%	17%
Keski-Nisula K et al., 2003 (N=534) [33]	Finland	4-7.8 y	2.2%	7.5%
Schopf P, 2003 (N=2326) [35]	Germany	6-7 y	7.91%	-
Bhayya DP et al., 2012 (N=1000) [5]	India	4-6 y	1.9%	0.6%
Reddy ER et al., 2013 (N=3000) [6]	India	6-10 y	4.49%	3.72%
Rauten AM, 2016 (N=147) [15]	Romania	6 y	5.79%	4.34%
		9 y	14.1%	8.97%
Olatokunbo daCosta O et al., 2016 (N=101) [34]	Nigeria	6,12 y	30.7%	5.0%
Ibrahim MM, 2018 (N=97) [24]	Egypt	6 y	20.0% (combined)	
		9 y	18.2% (combined)	
Rapeepattana S, 2019 (N=202) [14]	Thailand	8-9 y	23.9%	7.9%
Tungaraza JP, 2019 (N=667) [18]	Tanzania	6 y	8.5%	-
		9 y	7.2%	
Present study, India (N=616)	India	6 y	2.7%	0.7%
		9 y	8.2%	3.1%

[Table/Fig-13]: Prevalence of anterior and posterior crossbite [5,6,8,14,15,18,24,25,33-35].
(-= Not reported)

Author and country	Age (sample)	Prevalence (%)		
		Overjet	Overbite	Open bite
Hill PA, 1992 Scotland [8]	9 y (N=268)	2-5 mm=72.5% 6-9 mm=13.8% >10 mm=3.7%	-	2.3%
Keski-Nisula K et al., 2003, Finland [33]	4-7.8 y (N=534)	>4 mm=26.7% ≥6 mm=6.3%	>4 mm=33.8% >6 mm=5.0%	4.6%
Schopf P 2003, Germany [35]	6-7 y (N=2326)	4-6 mm=21.15% 7-9 mm=4.39% ≥10 mm=1.42%	-	>0 mm=7.87% ≥6 mm=0.09%
Shivkumar KM et al., 2009, India [4]	12-15 y (N=1000)	>2 mm=6.9%	-	>1 mm=2.1%
Mtaya M et al., 2009, Tanzania [37]	12-14 y (N=1601)	1-4.9 mm=73.3% 5-8.9%=11.1% >9 mm=0.4%	-	0-1.9 mm=8.9% >2 mm=0.2%
Singh A et al., 2011, India [26]	12 y (N=927)	>2 mm=1.8%	-	≥1 mm=1.8%
Bhayya DP et al., 2012, India [5]	4-6 y (N=1000)	2-4 mm=11.4% >4 mm=3.6%	0-2 mm=94.4% 2-4 mm=15.7% >4 mm=2.1%	1%
Olatokunbo da Costa O et al., 2016, Nigeria [34]	6-12 y (N=101)	2-4 mm=34.6% 5-7 mm=24.8% >7 mm=19.8%	Normal-34.7% Reduced-18.8% Increased-31.7%	14.8%
Ibrahim MM, 2018 Egypt (N=97) [24]	6 y	3.5-6 mm=4%	≥3.5 mm=4.0%	-
	9 y	3.5-6 mm=22.7% >6 mm=1%	≥3.5 mm=4.5%	>1 mm≤4 mm=2.1% >4 mm=4.1%
Rapeepattana S et al., 2019, Thailand [14]	8-9 y (N=202)	>3.1-5 mm=39.4% >5 mm=3.8%	< 1/3rd=43.3% >1/3rd=55.7%	1%
Tungaraza JP et al., 2019, Tanzania (N=667) [18]	6 y (n=317)	3.1-5 mm=10.1% 5.1-7 mm=6.6% 7.1-9 mm=2.2%	≤ 2/3rd=92.4% >2/3rd=5.4% ≥full=2.2%	1.1-2 mm=3.2% 2.1-3 mm=2.2% ≥3 mm=1.6%
	9 y (n=350)	3.1-5 mm=19.1% 5.1-7 mm=11.4% 7.1-9 mm=4.3%	≤ 2/3rd=87.7% >2/3rd=9.2% ≥full=3.1%	1.1-2 mm=5.4% 2.1-3 mm=0.6% ≥3 mm=1.4%
Present study, India (N=616)	6 y (n=297)	3.1-5 mm=2.7% 5.1-7 mm=1.7% >9 mm=0.7%	≤ 2/3rd=91.6% >2/3rd=5.4% ≥full=3.1%	≤ 1 mm=1% 1.1-2 mm=0.3% 2.1-3 mm=0.7%
	9 y (n=319)	3.1-5 mm=6.9% 5.1-7 mm=1.9% 7.1-9 mm=0.6% >9 mm=0.7%	≤ 2/3rd=87.5% >2/3rd=9.7% ≥full=2.8%	≤ 1 mm=0.63% 1.1-2 mm=0.9% 2.1-3 mm=0.6%

[Table/Fig-14]: Prevalence of overjet, overbite and open bite [4,5,8,14,18,24,26,33-36].
-=Not reported

Author	Country	Age (sample size)	Class-I	Class-II	Class-III
Shivakumar KM et al., 2009 [5]	India	12-15 y (N=1000)	91.6%	8.4% (Class-II, Class-III)	
Mtaya M et al., 2009 [37]	Tanzania	12 to 14 y (N=1601)	93.6%	4.4%	2%
Kumar DA et al., 2012 [27]	India	7 to 18 y (N=883)	95.6%	4.4% (Class-II, Class-III)	
Reddy ER et al., 2013 [6]	India	6 to 10 y (N=2135)	78.6%	13.9%	7.8%
Rauten AM et al., 2016 [15]	Romania	9 y (N=147)	53.84%	35.89%	7.69%
Ibrahim MM 2018 [24]	Egypt	9 y (N=97)	86.4%	12.4% (Class-II, Class-III)	
Present study	India	9 y (N=319)	75.6%	18.8%	4.36% FTP 1.25%

[Table/Fig-15]: Reported molar relation among mixed dentition children [5,6,15,24,27,37].
FTP: Flush terminal plane

Author	Country	Age and sample size	Lip incompetency (%)
Olatokunbo daCosta O et al., 2016 [34]	Nigeria	6, 12 yrs (N=101)	43.6%
Rapeepattana S, 2019 [14]	Thailand	8-9 yrs (N=202)	11.9%
Tungaraza JP, 2019 [18]	Tanzania (N=667)	6 yrs (n=317)	7.3%
		9 yrs (n=350)	15.7%
Present study	India (N=616)	6 yrs (n=297)	13.9%
		9 yrs (n=319)	16.2%

[Table/Fig-16]: Soft tissue component of IPION [14,18,34].

malocclusion identified among the population of this region. This is the first study conducted in India to examine malocclusion characteristics and evaluate treatment needs among children in their mixed dentition using IPION. Of all the studies done worldwide using this index, the present study has examined and reported all the components of IPION that reflect a developing malocclusion in children. Such evaluation aids in patient and parent education. The data from the present study contributes to establishing a baseline for further longitudinal studies, evaluation of causative factors of malocclusion, and planning and implementation of any preventive and interceptive treatment methods necessary.

Limitation(s)

Radiographic evaluation (for detection of supernumerary and unerupted permanent teeth) and appraisal of deleterious oral habits (to ascertain the causes of some of the malocclusion characteristics) were not done in the present study.

CONCLUSION(S)

Both cohorts demonstrated malocclusion and no gender dimorphism was detected. Nearly half of the nine-year-old children had interproximal caries and about 1.3% had impended eruption of first permanent molars. Mandibular teeth showed greater premature loss compared to the maxillary teeth in both age groups. Crossbites and supernumerary teeth were also detected which mandate action as and when detected. The nine-year-old children showed greater prevalence for all the examined components except premature tooth loss. This emphasises the importance of early detection of any developing malocclusion characteristics. The novel modifications of IPION to evaluate molar rotation and tipping are easier to use clinically. Conclusively, the present study reflects the malocclusion status in the examined cohorts and signifies the need for preventive and interceptive orthodontic treatments among them.

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