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ARQUIVOS EM ODONTOLOGIA

Malocclusion Severity Index in primary dentition: development and validation

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Aim: To develop and validate the Malocclusion Severity Index (MSI), which assesses the presence and severity of malocclusion in primary dentition.

Materials and Methods: 294 children aged 3-5 years were examined in 33 occlusal traits by calibrated examiners. Descriptive analysis, and univariate and multivariate linear regressions were performed. A final equation identified the influence of trait on the malocclusion severity of each child (lip coverage x 3) + (crowding x 2) + (diastema x 0.5) + (overbite x 0.5) + (anterior open bite x 1) + (anterior mandibular overjet x 2) + 3 (derived from the constant). The MSI value for each of the participants was calculated. The Kruskal-Wallis test determined the significance between each professional's assessment and the MSI score ($p < 0.05$). MSI was categorized as absent, mild, moderate and severe malocclusion. The Mann-Whitney test determined the discriminant validity.

Results: Some occlusal traits were independently associated with the perception of the severity of malocclusion by the professional ($p < 0.05$). Classification of the severity of malocclusion according to the MSI was associated ($p < 0.001$) with the perception of malocclusion by the professional, which demonstrated the discriminant validity of the instrument.

Conclusion: The MSI was effective in discriminating malocclusion in primary dentition by different degrees of severity.

Uniterms: child; index; malocclusion; orthodontics; pediatric dentistry.

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INTRODUCTION

Indices that assess and determine the orthodontic treatment need/severity of malocclusion have been widely applied in epidemiological studies worldwide[1-3]. Normally, these indices take into account some form of hierarchization of the collected clinical data in order to produce a final numerical value that characterizes the orthodontic treatment need and/or severity of malocclusion[4].

Studies present a wide variation in the prevalence of malocclusion in primary dentition, ranging between 32.5% and 87%[5,6]. This high prevalence variation can be due to the adoption of different diagnostic criteria[7]. Accordingly, a critical analysis of the literature reveals that, until now, almost all the developed indices have been developed to individuals who are in mixed or permanent dentition stages. This is a major limitation since occlusal alterations present in primary teeth can persist or get worse during the transition to permanent dentition[8-10]. Besides that, there are some evidence the malocclusion can exert a negative impact on the oral health-related quality of life (OHRQoL) of children and their families[11].

To date, the indices developed to be applied in primary dentition[12,13] present methodological limitations, such as time consuming and no validation process. In this context, malocclusion assessment in primary dentition has been restricted to the most prevalent occlusal traits, such as cross bite, overjet, open bite and

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crowding[6,7]. The professional's perception of malocclusion in the primary dentition becomes imperative because its assessment is focused on objective guidelines, standards, angles and ideal proportions[14], prioritizing function and occlusion[15]. Currently, there are no properly validated orthodontic indices applied to primary dentition that could establish normative criteria associated with the perception of the professional. An index with such characteristics could contribute to estimate prevalence, to public policy planning, to better establish treatment priorities, to help facilitate communication between professionals and to provide diagnostic parameters for carrying out treatments and epidemiological surveys.

Therefore, the aim of this study was to report the development and validation of an instrument denominated the Malocclusion Severity Index (MSI) that assesses the presence and severity of malocclusion in the primary dentition.

MATERIALS AND METHODS

ETHICAL ASPECTS

This study received approval from the Human Research Ethics Committee of the Federal University of Vales do Jequitinhonha e Mucuri, protocol 181/10. All parents/caregivers signed a statement of informed consent.

STUDY DESIGN

Initially, a cross-sectional study was carried out with children aged three to five years of age, attending public preschools and kindergartens in the city of Diamantina Only children with complete primary dentition and unerupted permanent teeth were eligible for the study. Children who were under or had had orthodontic treatment or missing any primary teeth were excluded. Participants were randomly selected from a population of 2025 preschool children of the same age group. For such, a two-stage sampling method was employed. The first stage was the randomization of all schools in the city. In the second stage, classes were randomly chosen from the schools selected. Then, all children belonging to the selected classrooms were invited to participate. The children who were allowed to participate in the study were evaluated through a clinical oral examination and their parents responded a sociodemographic questionnaire.

CALIBRATION PROCESS

Prior to data collection, the examiners underwent a training exercise and a calibration for assessment of key malocclusion traits. The training exercise was performed using images from different clinical situations of malocclusion in the primary dentition. Thirty three occlusion trais were considered, including relationship between second molars and canines, arch types and format, overjet, posterior and anterior crossbite, lip coverage, primate space, anterior open bite, crowding, facial type, overbite, midline deviation and diastema, and perception of malocclusion (VAS).

Calibration was carried out through clinical oral examinations of 30 children (not part of the main study), on two separate occasions, with two-week intervals between examinations. Minimum intraclass correlation coefficient for continuous variables was 0.85 (95% CI: 0.78-0.89) and minimum Kappa value for categorical variables was 0.88 (95% CI: 0.71-0.93).

PILOT STUDY SAMPLE SIZE CALCULATION

A pilot study was conducted with 30 children to help determining the minimum sample size required for the main study. These children did not participate in the main study. As result of the pilot study, no modifications were necessary to the proposed methodology.

Based on the pilot study, sample size was calculated as follows: a standard deviation of 2.9 related to the perception of the professional on the child's malocclusion, a 1-point of difference to be detected, a significance level of 5% and a test power of 95% for a two-tailed hypothesis were considered. In addition, a Deff effect of 1.2 and a 20% non-response rate were added, resulting in a sample of 315 children.

DATA COLLECTION

A committee made up of five calibrated orthodontists conducted the clinical oral examinations of the preschool children under natural light, with the aid of mouth mirrors, tongue depressors and a millimetric periodontal probe, complying with biosafety norms. Data were recorded on charts specially developed for the study. The clinical examination included 33 occlusal traits, divided as follows:

Terminal relationship of dental arches (relation between the second primary molars): flush terminal plane, mesial step and distal

step[16]. Relationship between canines: class I, class II and class III[17]. Maxillary and mandibular arch types: type I and type II[16]. Maxillary arch format: U-shaped or V-shaped. Overjet: ≤ 2 mm or > 2 mm[17] Posterior crossbite: absent, unilateral or bilateral[17]. Anterior crossbite: absent or present[17]. Lip coverage: adequate or inadequate, according to the type of lip seal, passive or active, respectively[17]. Primate space: presence in both hemiarches, presence only in one hemiarch or absent in both hemiarches[16]. Anterior open bite: absent or present[18]. Crowding: absent, present in one hemiarch or present in both hemiarches[16]. Facial type (clinical evaluation considering proportions of facial thirds): mesocephalic, dolichocephalic or brachycephalic[19].

The continuous variables were collected in accordance with criteria established by Cons et al[20]. However, individuals with missing any primary teeth were excluded to enable the exclusive application in the primary teeth.

The following occlusal traits (anterior maxillary and mandibular irregularity, overjet, open bite, overbite, midline deviation and diastema) were measured quantitatively by a millimetric periodontal probe, and computed rounding to the closest millimeter.

The largest anterior maxillary irregularity was characterized as rotation or displacement of the tooth from the normal alignment. The four incisors in the maxillary arch were examined in order to register the greater irregularity. The probe tip was placed in contact with the vestibular surface of the more rotated or lingualized incisor. The probe was positioned parallel to the occlusal plane and at right angle to the normal arch line. A similar procedure was performed to measure the larger anterior mandibular irregularity.

The largest anterior maxillary overjet was registered with the teeth in centric occlusion, considering the distance from the vestibular incisal edge of the most prominent maxillary incisor to the vestibular surface of the corresponding mandibular incisor, with the probe parallel to the occlusal plane. When the occlusion was in an edge-to-edge position, a zero value was attributed. The largest anterior mandibular overjet was recorded when any of the mandibular incisors were anteriorly protruded or vestibularized in relation to the corresponding maxillary incisor.

The open bite was evaluated by the distance, in millimeters, between the incisal edges of the examined teeth. The overbite was classified by measuring, in millimeters, the largest vertical overlap. The midline deviation was recorded when the child, in centric occlusion, did not present coincidence between the superior and inferior midline. In such cases, the distance was measured, in millimeters, from the inferior midline to the superior midline in the horizontal direction. Midline diastema was recorded, in millimeters, between the mesial surfaces of the maxillary central incisors at any level.

The perception of the orthodontists (committee) according to a 10-point visual analogical scale was classified as follows: the zero code was attributed to children without malocclusion. Then, the values from 1 to 10 were divided into percentiles (25th, 50th and 75th). Thus, it was possible to transform a quantitative variable into ordinal categorical: 0 = absent, 1 to 2 = mild malocclusion, 3 to 6 = moderate malocclusion, 7 to 10 = severe malocclusion.

The following sociodemographic data were also collected by a structured questionnaire: sex and age of each preschool child, parents' marital status, parental education level, family income, number of children and number of people living with the same income.

DATA ANALYSIS

Data analysis was performed using the Statistical Package for Social Sciences (SPSS for Windows, version 20.0; SPSS Inc., Chicago, Ill., USA) software. Initially, absolute and relative frequencies of variables and descriptive statistics (mean, standard deviation, median) were performed. Normality tests were performed to check the normality of the data distribution.

INDEX DEVELOPMENT

The development of the MSI comprised the assessment of all 33 children's occlusal features by calibrated examiners. After that, accurate statistical analysis was applied to determine an equation that offered a normative value that classified the severity of the malocclusion in congruence with the professional's determination. Once the data were shown to have a normal distribution, a univariate linear regression analysis was conducted to identify the significant variables related to the perception of malocclusion by the professional (dependent variable). Thus, all variables that had $p < 0.20$ were included in the multivariate linear regression. The results of multivariate analyzes offered a B value that was determined as the weight that each occlusal feature that remained associated would have in the final equation. In addition, a constant was also presented in the final result.

INDEX VALIDATION

After determining the linear regression, the MSI equation was calculated for each of the 294 participants. In the next phase, the Kruskal-Wallis test was performed to determine the significance between the assessment made by the professional and the MSI score. The categorization of the MSI was performed through the median of the MSI scores of the children participating in the study associated with the perception of the professional in relation to the severity of malocclusion, categorized as absent, mild, moderate and severe. Finally, the post-hoc Mann-Whitney test determined the discriminant validity among the evaluation categories of the severity of malocclusion.

RESULTS

A total of 294 children participated in the study. All parents/caregivers were interviewed and adequately answered the sociodemographic questionnaire. The mean age of the children was 4.35 years (SD = 0.76) and 50.7% were male. Lack of participation occurred mainly due to the absence of children on the days of examination.

The univariate analysis (Table 1) revealed that the characteristics associated with increased perception of the severity of malocclusion were: overjet, lip coverage, terminal relationship of left and right second primary molars, maxillary arch type, midline deviation, maxillary primate space, maxillary arch format, primate space (hemiarch), crowding (hemiarch), anterior open bite, anterior crossbite, posterior crossbite, anterior crowding (segment), largest anterior maxillary irregularity (in mm), largest anterior mandibular irregularity (in mm), anterior maxillary overjet (in mm), anterior mandibular overjet (in mm) and anterior open bite (in mm).

Table 1. Univariate analysis (enter and stepwise) of the independent variables and perception of the professional regarding malocclusion.

Independent variables	B	Standarderror	Beta	95% CI (Lower-Upper)		T	p*
Overjet	1.10	0.41	0.15	0.28	1.92	2.65	0.008
Lip coverage	4.08	0.69	0.33	2.73	5.44	5.93	< 0.001
Overbite (mm)	0.25	0.19	0.07	- 0.12	0.62	1.31	0.191
Terminal relationship of left second molar	0.53	0.17	0.17	0.18	0.86	3.03	0.003
Terminal relationship of right second molar	0.45	0.18	0.15	0.10	0.80	2.56	0.011
Left canine relationship	0.24	0.18	0.07	- 0.12	0.61	1.30	0.194
Right canine relationship	0.28	0.19	0.05	- 0.08	0.66	1.51	0.131
Maxillary arch type	1.90	0.34	0.31	1.24	2.57	5.63	< 0.001
Mandibular arch type	0.12	0.34	0.02	- 0.55	0.80	0.37	0.713
Midline deviation (mm)	0.82	0.17	0.27	0.48	1.16	4.76	< 0.001
Maxillary primate space	1.91	0.34	0.31	1.24	2.58	5.63	< 0.001
Mandibular primate space	1.93	0.34	0.03	- 0.48	0.87	0.56	0.577
Maxillary arch format	1.27	0.36	0.20	0.56	1.99	3.52	< 0.001
Primate space (hemiarch)	0.59	0.19	0.17	0.21	0.98	3.03	0.003
Crowding (hemiarch)	1.82	0.24	0.40	1.34	2.30	7.46	< 0.001
Anterior open bite	3.84	0.49	0.41	2.87	4.80	7.83	< 0.001
Anterior crossbite	3.30	0.38	0.45	2.55	4.04	8.72	< 0.001
Posterior crossbite	3.36	0.60	0.31	2.17	4.54	5.58	< 0.001
Facial type	- 0.38	0.27	- 0.08	- 0.92	0.14	- 1.42	0.155
Absence of maxillary teeth	- 0.12	0.24	- 0.29	- 0.59	0.35	-0.50	0.619
Absence of mandibular teeth	0.11	0.57	0.01	- 1.01	1.24	0.20	0.839
Anterior crowding (segment)	1.66	0.25	0.36	1.16	2.15	6.56	< 0.001
Diastema (mm)	0.23	0.16	0.08	- 0.08	0.56	1.45	0.147
Largest anterior maxillary irregularity (mm)	1.56	0.23	0.36	1.10	2.01	6.70	<0.001
Largest anterior mandibular irregularity (mm)	0.60	0.23	0.15	0.14	1.07	2.55	0.011
Anterior maxillary overjet (mm)	- 0.48	0.11	- 0.25	- 0.70	- 0.27	- 4.42	< 0.001
Anterior mandibular overjet (mm)	2.04	0.28	0.39	1.49	2.59	7.31	< 0.001
Anterior open bite (mm)	0.96	0.13	0.40	0.71	1.21	7.45	< 0.001

*Univariate linear regression

The multivariate linear regression analysis (Table 2) showed that the variables independently associated with the perception of the severity of malocclusion by professionals were: lip coverage ($p < 0.001$), crowding ($p < 0.001$), diastema (in mm) ($p = 0.002$), anterior open bite (in mm) ($p < 0.001$), overbite (in mm) ($p = 0.010$) and anterior mandibular overjet (in mm) ($p < 0.001$).

Table 2. Multivariate analysis (enter and stepwise) of the independent variables and the perception of the professional regarding malocclusion.

Independent variables	B	Standar-derror	Beta	95% CI (Lower-Upper)		T	p*
Lip coverage	2.92	0.53	0.23	1.87	3.97	5.47	< 0.001
Crowding	1.54	0.19	0.34	1.16	1.93	7.87	< 0.001
Diastema (mm)	0.38	0.12	0.13	0.14	0.61	3.14	0.002
Anterior open bite (mm)	0.86	0.10	0.35	0.66	1.06	8.52	< 0.001
Overbite (mm)	0.36	0.14	0.11	0.08	0.63	2.59	0.010
Anterior mandibular overjet (mm)	1.75	0.22	0.34	1.32	2.18	8.04	< 0.001
Constant	2.87	0.18	-	2.51	3.22	15.89	< 0.001

*Multivariate linear regression

The MSI was developed based on the regression equation. The MSI has six components and one constant. For a better application, the coefficients were rounded (Table 3). MSI equation = (lip coverage x 3) + (crowding x 2) + (diastema x 0.5) + (overbite x 0.5) + (anterior open bite x 1) + (anterior mandibular overjet x 2) + 3 (derived from the constant).

Table 3. Components of the MSI regression equation and their real and rounded coefficients (weights).

MSI components	Regression coefficients	
	Real weight	Rounded weight
1. Lip coverage (0 = adequate; 1 = inadequate)	2.92	3
2. Crowding (0 = absent; 1 = present in one hemiarch; 2 = present in both hemiarches)	1.54	2
3. Diastema measurement in millimeters	0.38	0.5
4. Anterior open bite measurement in millimeters	0.86	1
5. Overbite measurement in millimeters	0.36	0.5
6. Anterior mandibular overjet measurement in millimeters	1.75	2
Constant	2.87	3
Total	10.68	12

According to the MSI, the classification of the severity of malocclusion (absent, mild, moderate and severe) was statistically associated ($p < 0.001$) with the perception of malocclusion by the professionals, which demonstrated adequate discriminant validity of the instrument (Table 4). The values included in Table 5 were based on MSI scores from each category of severity of malocclusion.

Table 4. Discriminant validity of the MSI regarding severity of malocclusion.

Severity of malocclusion Professional	Absent	Mild	Moderate	Severe	p*
	Median (25th - 75th)	Median (25th - 75th)	Median (25th - 75th)	Median (25th - 75th)	
	3.5^{A**} (3.0-4.0)	4.0^{B**} (3.0-5.0)	5.5^{C**} (4.5-7.0)	9.0^{D**} (7.0-9.0)	< 0.001*

*Kruskal-Wallis test **Different letters show statistical significance ($p < 0.001$) in the Mann Whitney test

After determining the MSI equation, all children included in the study obtained their MSI score. In the discriminant validity analysis, it was possible to obtain scores that classified the participants' malocclusion as absent, mild, moderate and severe, which was significantly associated with the professional's perception assessed by the Visual Analogue Scale ($p < 0.001$), which demonstrated adequate discriminant validity of the instrument (Table 4). In this way, it was possible to determine which MSI score indicated the severity of malocclusion in primary dentition (Table 5).

Table 5. Classification of the severity of malocclusion in primary dentition according to the MSI.

Severity	MSI score
Absent	3.0 – 4.0
Mild malocclusion	4.1 – 5.4
Moderate malocclusion	5.5 – 8.9
Severe malocclusion	≥ 9.0

DISCUSSION

This study presented the development and validation of an index to identify and assign scores to the severity of malocclusion in preschool children at the stage of primary dentition. For an orthodontic index to be able to demonstrate its applicability in both epidemiological studies and clinical practice, it should ideally present two criteria: reliability and validity[21,22].

The validity of an index refers to its ability to measure what it purports to measure[23]. In this present study, statistical findings of the categorization of malocclusion as absent, mild, moderate or severe, according to the MSI, showed that the index was able to discriminate the different levels of malocclusion in primary dentition. Furthermore, for an index to be considered reliable or with less chance of error, the scores acquired in the evaluations should be reproducible even when a single examiner repeats the assessment in the same patient. In addition, the index should be of easy understanding, allowing quick recording of occlusal characteristics, either by dental professionals or not[21,22]. In this study, there was good inter- and intra-examiner agreement and a consensus among examiners about the ease of understanding and the speed to record (2 minutes on average, depending on child collaboration) was achieved. However, further studies are needed to test the reproducibility of the MSI, when performed by other dental professionals.

According to Foster and Menezes[24], the addition of coefficients (weights) increases the subjectivity of the assessment, since the concept that certain types of occlusal deviations require more treatment than others is highly subjective. In this present study, the findings of linear regression analysis showed that the more prevalent and/or the higher the measurements of the occlusal traits that remained statistically significant, the worse the child's MSI score will be and, consequently, the greater the severity of malocclusion in the primary dentition. Moreover, Jenny and Cons[16] stated that the equation loses relatively little precision when the regression coefficients (weights) are rounded. This small sacrifice in precision is offset by its convenience in many clinical and research applications[20].

The orthodontic index most widely used and adopted by the World Health Organization (WHO) is the Dental Aesthetic Index (DAI)[20], which was developed through the analysis of plaster casts for the evaluation of occlusal deviations present in the mixed and permanent dentition. Like in the DAI development, the MSI presents occlusal traits that should be evaluated and multiplied by their coefficients (weights) properly rounded, aimed at obtaining a final numeric value that determines the severity of malocclusion of the patient. However, the MSI presented its development according to clinical oral examinations in children, which may indicate a closer to real life assessment of each occlusal trait in determining the severity of malocclusion in the primary dentition.

In this present study, the factors that showed greatest impact on the negative perception of the professional about the malocclusion in the primary dentition were: lip coverage, midline diastema, crowding, anterior open bite, overbite and anterior mandibular overjet. A critical analysis of the literature shows the relevance of each of these variables in the development of a possible malocclusion.

Hulsey[25] argued that lip seal must be passive and easy, as lip positioning can

indicate tooth shape and alignment. Gkantidis et al.[26] linked diastema to both genetic and environmental factors, often seeing it as a normal feature of growth, especially in primary and mixed dentition. Tschill et al.[27] noted that crowding in primary dentition often predicts future crowding in permanent teeth, highlighting the need for space management strategies. The use of the Malocclusion Severity Index (MSI) in primary dentition is therefore crucial to monitor occlusal development and prevent malocclusion issues like crowding[28].

Labial incompetence is a common orofacial characteristic in children with anterior open bite, and it can affect their oral health-related quality of life (OHRQoL), eating, and speech[11,29]. Prevention of anterior open bite is important even in primary dentition due to its significant impact, though spontaneous correction during the transition to permanent dentition is possible[30,31]. Overbite has been shown to interfere with mandibular movements and may harm the temporomandibular joint if left untreated[32]. However, there is controversy in the literature regarding cut-off values for deep or normal overbite in primary dentition, and standardized measurements using a periodontal probe can aid in determining its prevalence and severity[27,32,33].

Anterior crossbite, if left untreated, can negatively affect aesthetics, cause dental damage, lead to gingival retraction, temporomandibular dysfunction, and alter mandibular and maxillary growth[33-36]. Lastly, overjet was unexpectedly not associated with negative perceptions of malocclusion, contradicting findings of its high prevalence in primary dentition[37,38]. Bugaighis[39] suggested that overjet in primary dentition may not accurately predict its presence in permanent dentition, where it may have a greater impact on malocclusion severity.

Although occlusal classifications are useful for clinical descriptions, their obvious limitation is the simplification of the various characteristics that compose the occlusion into a single measure[24]. Despite the relevance of creating a standardized method for assessing malocclusion in primary dentition, perhaps psychological and skeletal parameters can express greater influence when establishing treatment priorities[40]. Also, if a malocclusion present in primary teeth is not treated, it can remain or get worse in the permanent dentition[8-10]. It is appropriate to point out the need to assess the impact of malocclusion on the quality of life of preschool children through a specific instrument, to be able to elucidate the perception of the child and his/her family, about the negative impact of the severity of malocclusion in the primary dentition.

The variability of the studied methods and the different findings of epidemiological data reflect the divergent criteria of interpretation of relevant occlusal deviations. Therefore, the use of an index such as MSI can make the determination of malocclusion in primary dentition a standardized and global practice.

Finally, the MSI has some advantages that require considerations. It can be considered an easy-to-use index that can be done clinically without the need for radiographs or plaster models. Also, it may help pediatric dentists to determine future orthodontic treatment need and need for referrals to orthodontists and it will help parents/caregivers to better prepare themselves for possible financial expenses with orthodontic treatment need.

This study has some limitations that need to be acknowledged. First, the same population was used in both development and validation phases and sample did not present equal number of participants in the three main malocclusion classes. In addition, validation phase was done by the same examiners that worked on index development, which could have incorporated some degree of bias. Finally, some characteristics of malocclusions were derived from averages.

CONCLUSION

The MSI revealed to be effective for the discrimination of malocclusions in primary dentition by different degrees of severity (absent, mild, moderate and severe). This measure can be used by pediatric dentists and researchers in clinical and epidemiological studies.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTION

L.S.M, M.L.R.J participated in conception and design of the work, analyzed and interpreted data of the work, critically revised the manuscript, approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

M.A.H., T.S.P., P.A.M.J, participated in data acquisition, analysis, interpretation of data, drafted the manuscript, approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

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