Comparison of intra-oral and study cast measurements in the assessment of malocclusion

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SUMMARY Malocclusion assessment methods are based on registrations and measurements made on study casts, which requires that impressions be taken. In addition to being costly and time-consuming, this process can be unpleasant for very young children. Therefore, the aim of this study was to evaluate the reliability of intra-oral measurements that compute a malocclusion index score to determine malocclusion severity in the mixed dentition. The research was part of a longitudinal study in Slovenia on a sample of 530 3-year-old children. At 8 years of age (mean 8.5 years, standard deviation 0.2), a cohort of 101 children (44 boys, 57 girls) was randomly selected in a cross-sectional study. Quantitative registrations of space and occlusal anomalies were performed intra-orally as well as on study casts. Kappa (κ) statistics were used to evaluate the agreement between clinical and study cast malocclusion assessments. Systematic bias of measurements was tested using Wilcoxon's signed rank test.

The results showed complete agreement between the two measurements for anterior crossbite, anterior open bite and overjet scores ($\kappa = 1$); excellent reliability for the buccal segment relationship ($\kappa = 0.93$), transverse occlusion of posterior teeth ($\kappa = 0.87$); and substantial agreement for overbite ($\kappa = 0.79$) and midline deviation ($\kappa = 0.71$). For the remainder of the traits the agreement was moderate: rotation of incisors ($\kappa = 0.58$), crowding of upper incisors ($\kappa = 0.51$), axial inclination of teeth ($\kappa = 0.44$) and lower incisor crowding ($\kappa = 0.41$). Intra-orally small, but statistically significant scoring of lower incisor rotation and crowding was identified. On the study casts the most favourable axial inclination was found for buccal segment occlusion. Overall classification into severity grades, based on the total malocclusion score, showed excellent agreement between the two methods ($\kappa = 0.89$), without statistically significant bias.

Malocclusion assessment, recorded and measured intra-orally, is as reliable as assessment on study casts. The proposed method can be used in screening, in epidemiological studies and in clinical orthodontic assessment.

Introduction

The demand for orthodontic treatment is increasing in many countries. Because of this, rational planning of orthodontic preventive measures on a population basis among children in various stages of development is essential. This need highlights the importance of screening methods and epidemiological studies in order to obtain knowledge of the prevalence of malocclusion and the need for orthodontic treatment (Thilander *et al.*, 2001).

Methods that describe, evaluate and classify occlusion can basically be divided into qualitative and quantitative (Helm, 1970; Tang and Wei, 1993; Uğur *et al.*, 1998). Malocclusion assessment methods are designed for different purposes (Shaw *et al.*, 1995; Thilander *et al.*, 2001) and are divided into diagnostic classification (Angle, 1907; Ackermann and Proffit, 1969), epidemiological (Björk *et al.*, 1964; Summers, 1971; Baume *et al.*, 1974; Burden *et al.*, 2001), treatment need or priority (Grainger, 1967; Salzmann, 1968; Lundström, 1977; Cons *et al.*, 1986; Brook and Shaw, 1989; Espeland *et al.*,

1992), treatment outcome (Eismann, 1974, 1980; Berg and Fredlund, 1981; Richmond *et al.*, 1992) and complexity and need (Daniels and Richmond, 2000) indices.

The methods differ not only in the choice of the morphological or functional criteria used in the malocclusion assessment, but also in the mode of evaluation, which can be performed on study casts (Summers, 1971; Eismann, 1974, 1980; Farčnik *et al.*, 1985, 1988; Brook and Shaw, 1989), clinically (Baume *et al.*, 1974; Cons *et al.*, 1986; Brook and Shaw, 1989) or using both of these modes (Grainger, 1967; Brook and Shaw, 1989; Ghafari *et al.*, 1989; Uğur *et al.*, 1998; Daniels and Richmond, 2000).

With increasing interest in the early detection and treatment of malocclusions and a corresponding emphasis on preventive procedures, it would be beneficial to collect information on patients at younger ages (Trottman and Elsbach, 1996). Treatment of some malocclusions should be started in the primary and early mixed dentition stages, as it is generally believed that the status of the primary occlusion affects the

development of the permanent occlusion (Thilander *et al.*, 1984; Farčnik *et al.*, 1985, 1988; Kurol and Berglund, 1992; Trottman and Elsbach, 1996). Posterior crossbites are one of the most prevalent malocclusions of the primary dentition and if left untreated may lead to craniofacial asymmetry (Thilander *et al.*, 1984; Kurol and Berglund, 1992; Viazis, 1995). It is, therefore, recommended that every child between 9 and 10 years of age should be screened at least once during occlusal development by a dental practitioner with special training in orthodontics (Rölling, 1978; Heikinheimo *et al.*, 1987; Burden *et al.*, 1994; Solow, 1995).

Eismann (1974, 1980) developed a method for evaluating the efficiency of orthodontic treatment and treatment need in the permanent dentition, based on determination of morphological criteria in a method analogous to that applied by Björk *et al.* (1964). In order to assess malocclusion in the early dental development period, the Eismann method was modified for the primary and mixed dentitions (Farčnik *et al.*, 1985, 1988) and used in Slovenia in a longitudinal study as an indicator of interceptive treatment results (Korpar *et al.*, 1994).

Both of these methods are performed on study casts (Eismann, 1974; Farčnik *et al.*, 1985). However, the preparation of study casts requires that impressions be taken, and this is often unpleasant, especially for very young children. In addition, the procedure itself can be costly and time-consuming and measurements have proved to be complicated in daily use (Solow, 1995).

Therefore, the aim of this study was to evaluate the reliability of intra-oral measurements that compute the malocclusion index score to determine malocclusion severity in the mixed dentition.

Subjects and methods

The research was part of a longitudinal study (Farčnik *et al.*, 1986) in Slovenia on a sample of 530 3-year-old children. At 8 years of age (mean 8.5 years, standard deviation 0.2), a cohort of 101 children (44 boys, 57 girls) was randomly selected in a cross-sectional study.

The clinical examinations were performed by a single experienced orthodontist (MO) trained in the use of the index. During the intra-oral examination, measurement of 10 morphological signs was carried out. Impressions were then taken of the upper and lower dentitions for study casts. One month later the measurements were repeated on the study casts. For each set of measurements, registrations were carried out according to Eismann (1974, 1980), modified for the mixed dentition by Farčnik *et al.* (1985). For measurements of linear dimensions a metric ruler (Zürcher modell, Dentaurum 042-751, Ispringen, Germany), accurate to 1/10 mm, was used. Angles were measured with a protractor (Eismann, 1974) to determine the rotation of the incisors and the axial inclination of the teeth.

Intra-arch assessment involved measurement of incisor crowding and rotation of the incisors and axial inclination of the teeth. For inter-arch measurements, overbite, anterior open bite, overjet, reverse overjet, anterior crossbite and buccal segment relationships were recorded.

All morphological signs, measured intra-orally as well as on study casts and expressed in millimetres and degrees, were weighted and scored against the evaluation table for each subject (Eismann, 1974). The weighted sum of recorded occlusal traits thus represented the total malocclusion index score—where the first was measured intra-orally and the second was measured on study casts. The overall malocclusion scores were categorized according to Eismann (1977, 1980) in terms of mild (1–15), moderate (16–40), severe (41–65) and very severe (over 65) malocclusion.

Statistical analysis

Kappa (κ) statistics were used to evaluate the agreement observed between intra-oral and study cast individual measurements. κ values equal to 0 represent agreement equivalent to that expected by chance, while 1 represents perfect agreement. In accordance with Landis and Koch (1977), the following kappa interpretation scale was used: poor to fair (below 0.40), moderate (0.41–0.60), substantial (0.61–0.80) and almost perfect (0.81–1.00).

Wilcoxon's signed rank test was used for statistical analysis of the bias between clinical and study cast malocclusion assessments. A non-parametric test was used because of the non-normal distribution of the data. For the analysis, SPSS for Windows version 10.1 (SPSS Inc., Chicago, IL, USA) was used.

Results

The results for the clinical and study cast malocclusion assessments are shown in Table 1. κ statistics indicated agreement for anterior open bite, anterior crossbite and overjet. There was excellent agreement for overbite, midline deviations, buccal segment relationship and transverse occlusion of the posterior teeth. Moderate agreement was found for upper and lower incisor crowding, and for axial inclination of the teeth and rotation of the incisors.

Systematic bias was found for rotation and crowding of the incisors in the lower arch, which tended to be scored slightly worse intra-orally. Axial inclination of the teeth and the buccal segment relationship were scored poorly on study casts. As can be seen from Table 1, despite statistical significance between the two methods, the measurements were in most cases equal (for example, rotation of incisors was scored equally in 81 per cent of cases).

The classification of malocclusion scores into four grades of severity according to intra-oral and study cast assessments is shown in Table 2.

Table 1 The difference and agreement between the morphological signs scores evaluated intra-orally and on the study casts assessed by Wilcoxon's signed rank test and kappa (κ) statistics.

	Intra-oral score higher	Intra-oral score lower	Equal scores	Wilcoxon Z	P	κ
Rotation of incisors	14	6	81	–2.130	0.033*	0.58
Anterior crossbite	0	0	101	–2.130	1.000	1
Anterior open bite	0	0	101	–2.130	1.000	1
Axial inclination	13	27	61	–2.368	0.018*	0.44
Overbite	4	2	95	–0.333	0.739	0.79
Overjet	0	0	101	–0.333	1.000	1
Midline deviation	11	6	84	–0.894	0.371	0.72
Buccal segment relationship	0	6	95	–2.271	0.023*	0.93
Transverse occlusion	5	3	93	–0.499	0.618	0.87
Upper incisor crowding	15	15	71	–0.246	0.806	0.51
Lower incisor crowding	16	6	79	–2.495	0.013*	0.41
Malocclusion severity score	5	1	95	–1.63	0.102	0.89

*Statistically significant $P < 0.05$.

Table 2 Classification of malocclusion scores into grades of severity.

Intra-orally	Study casts				Total
	0–15 (mild)	16–45 (moderate)	46–65 (severe)	66 and above (very severe)	
0–15 (mild)	**53**	1			54
16–45 (moderate)	4	**35**			39
46–65 (severe)		1	**6**		7
66 and above (very severe)				**1**	1
Total	57	37	6	1	101

Bold numbers represent equal intra-orally and study cast-determined grades of severity.

In five patients the intra-orally recorded score grade was lower, in one patient higher and in the remaining 95 the scores were equal. κ statistics for the agreement between the two methods yielded a value of 0.89 (excellent agreement). The analysis of bias using Wilcoxon's signed rank test revealed no statistically significant difference ($Z = –1.6$, $P = 0.1$) between the malocclusion severity grade obtained intra-orally or on the study casts.

Discussion

Malocclusion assessment methods for screening and epidemiological studies are designed either for study cast measurements (Helm, 1970; Summers, 1971; Ghafari *et al.*, 1989) or for clinical use (Baume *et al.*, 1974; Cons *et al.*, 1986; Brook and Shaw, 1989; Uğur *et al.*, 1998; Burden *et al.*, 2001).

Obtaining casts involves clinical and laboratory procedures and is thus a costly and time-consuming method for assessing malocclusion. Conversely, performing the measurements on casts is more pleasant for the examiner, who can manually handle the cast while sitting at a table under excellent lighting using rulers (protractor, gauge) designed for this specific purpose.

Although there are certain advantages and conveniences in undertaking measurements on casts, obtaining casts may not be possible under many field conditions (very young children, taking impressions, costs, time) and thus for consistency the assessments are limited to direct observations.

In clinical orthodontics, malocclusion assessment remains problematic. Index scores have been shown to have acceptable reliability (Brook and Shaw, 1989; Richmond *et al.*, 1992) when measured on casts. Only the study by Keeling and Wheeler (1996) reported the reliability of scoring components of malocclusion in the clinical settings.

Most of the methods were developed for malocclusion assessment in the permanent dentition (Cons *et al.*, 1986; Brook and Shaw, 1989), and only the Occlusal Index (Summers, 1971) was designed for different stages of dental development. In Slovenia, the Eismann method, modified for the mixed and primary dentitions, has proved to be a valid diagnostic tool for malocclusion assessment in early dental developmental stages (Farčnik *et al.*, 1985, 1988).

In the present study, perfect agreement was found for three occlusal traits, substantial for four traits and moderate for both the angular measurements and crowding

of incisors. Agreement between the two methods was better for all traits compared with the results achieved by Keeling and Wheeler (1996). The reason for this could be that the registrations were performed in a practice setting on a dental chair, with good lighting and no time limitation.

Bias between the two measurements was found for rotation of incisors, axial inclination of teeth, lower incisor crowding and buccal segment relationship (Table 1). Rotation and axial inclination of teeth were measured using a protractor, which was more difficult to use intra-orally than on casts, thus accounting for the bias between the two measurements.

The difference between the two measurements for buccal segment relationship could be due to viewing the posterior region intra-orally from a different perspective than from study casts. An incorrect registration can result from casts that can easily move when articulated by hand. Although the data are based on the use of habitual (centric) occlusion, an obvious difference could be due to the mandibular position determined by the patient (child) as opposed to that determined on study casts (Keeling and Wheeler, 1996).

The reliability of incisor crowding measurements may be related to the ordinal manner of scoring. Crowding was recorded according to the method of Björk et al. (1964) and was evaluated and scored according to Farčnik et al. (1985). With incisor crowding, the teeth are positioned lingually or buccally and are also rotated or inclined, as a result of which the mesio-distal crown diameters and the two incisor segments are more difficult to determine. Different cut-offs were applied intra-orally and on the casts, which could thus result in systematic bias. Apart from the difficulties in intra-oral crowding assessment, differences could also be due to completion errors on the data collection forms rather than to a true bias. In other methods, space condition assessment records the potential tooth displacement and is as such not reliable (Grainger, 1967; Brook and Shaw, 1989; Ghafari et al., 1989; Tang and Wei, 1993; Uğur et al., 1998). Crowding has been found to be the most common anomaly (Helm, 1970; Eismann, 1980; Farčnik et al., 1985; Brook and Shaw, 1989; Ghafari et al., 1989; Uğur et al., 1998; Thilander et al., 2001). In the study by Thilander et al. (2001), crowding was recorded in more than half of the population with prevalence increasing from the early mixed to the permanent dentition. Due to the high prevalence of crowding, mixed dentition space analysis should be carried out in the screening of children for orthodontic treatment.

However, the results of this study indicated that the total malocclusion score composed of all the morphological sign scores, whether recorded intra-orally or on study casts, showed no systematic bias between the two methods (Table 1). Two occlusal traits tended to be scored worse intra-orally, and two were scored better; but in most cases the measurements were scored equally and thus malocclusion assessment between the two methods did not differ significantly.

The malocclusion indices were designed to interpret malocclusion severity objectively in terms of treatment priority. Eismann (1977) suggested classification into four grades of severity, into which the present sample was classified. Table 2 shows that an almost equal percentage of individuals were classified into severity grades according to both methods, with the corresponding κ as high as 0.89, indicating almost total agreement.

As there is no universally accepted method that defines all characteristics of a malocclusion, this is a multifactorial problem (Tang and Wei, 1993; Uğur et al., 1998). Application of the proposed method for malocclusion assessment is more favourable for very young children and requires less clerical time when compared with assessments based on study cast measurements. Thus, the modified method for malocclusion assessment in the mixed dentition can be used as an epidemiological tool for screening and in the identification of those children who can benefit most from orthodontic treatment. The cost–benefit of the method should be evaluated further in a longitudinal study.

Conclusions

The results obtained from studying the reliability of intra-oral measurements that compute the malocclusion index score lead to the following conclusions:

1. The malocclusion severity grade, defined by a total malocclusion score composed of all the morphological sign scores, showed almost perfect agreement and no bias between the intra-oral and study cast methods.
2. Malocclusion assessment in a clinical orthodontic setting based on intra-oral measurements is as reliable as assessment carried out on study casts. It is therefore proposed as the method of choice to be used in epidemiological studies, screening, and in clinical orthodontic assessment.

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