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Assessment of Malocclusion ComplexityUsing the American Board of Orthodontics' Discrepancy Index: An in-Vitro Study

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Abstract— Purpose: The objective of this study was to use the ABO-DI to assess the pre-treatment case complexity of the orthodontic clinic program of the Suez Canal University. Methods and material: The sample included120 unidentified pretreatment casts andcephalometric and panoramic radiographic records that were selected and collected from the orthodontic clinic program of the Suez Canal University.The DI scores were categorized into three degrees of DI complexity, low, moderate, or high complexity according to thetotal DI score. Results: No significant associations were found of DI with gender.Patients with ABO-DI low score was (31.6%), moderate score was (36.6%), while (31.6%) of the total sample had a severe ABO-DI score. Angle classifications showed a significant positive correlation with malocclusion complexity, As the classes increase from I to III, the malocclusion complexity increases. Conclusions: The DI was a relatively reliable index for measuring malocclusion severity.All the registrars had most of their cases in the moderate category. Thecephalometric parameter was the highest effect on DI score, and the lowest score was for lateral openbite.

KEYWORDS: American Board of Orthodontics, Discrepancy index, Complexity

INTRODUCTION

In contemporary orthodontics, the imperative of achieving precise pre-operative assessments is paramount for optimizing treatment outcomes, the significance of such assessments lies in the ability to provide an objective and standardized diagnosis of case difficulty, facilitating informed treatment planning and enhancing the overall quality of orthodontic care[(1)].

Case difficulty is generally subjective in clinical examination; nonetheless, it is related to case complexity, which can be measurable. Due to the lack of a reliable, valid, and consistent assessment of pretreatment case complexity, it has become a clinical issue for the orthodontic specialist. Over time, evidence-based orthodontics indexes that are quantitative and quantifiable have been developed to provide an objective evaluation of complexity, which may lead to a greater understanding of difficulty[(2)].

Among the various indices available for this purpose, the American Board of Orthodontics Discrepancy Index (ABO-DI) stands out as a valid tool, offering a systematic and comprehensive approach to evaluating malocclusions. The incorporation of an objective metric like the ABO-DI is instrumental in moving beyond subjective judgments, fostering a more evidence-based and standardized methodology in the field[3].

The ABO-DI has established its validity, reliability and is a widely accepted objective index. A number of studies uses the DI to assess orthodontic pretreatment complexity of universities, orthodontic clinics over time, compare treatment outcomes of universities to other universities, and also to compare the efficiency of finishing protocols[4-6].

Since there are no previous studies assessing the pretreatment complexity over time in Suez Canal University using an objective standardized index. Such studies should provide quantitative measures and statistics together with the routine subjective pretreatment assessment to give an insight not only to refine our understanding of case difficulty but also underscore the practical utility of the ABO index in enhancing the precision and effectiveness of orthodontic treatment planning.

MATERIALS AND METHODS

Study design:

This was a retrospective, descriptive, cross-sectional study which assessed data obtained from the pre-treatment records of patients who had been treated between 2019 and 2023 in the postgraduate orthodontic programme at SCU.This research project was approvedfrom the ethical committee of the faculty of dentistry, Suez Canal University **(# 280/2022)**.

Sample size calculation:

A minimum total sample size of 102 records will be sufficient to detect the effect size of 0.40 according and a power (1-β=0.95) of 95% at a significance probability level of $p<0.05$ partial eta squared of 0.14. The sample size was calculated according to G*Power software version 3.1.9.6.

Sample Size Calculation:

The **inclusion criteria** were as follows: (1)Unidentified pre-treatment records including study casts, panorama and cephalometric radiograph of patients indicated for treatment with fixed appliances in the orthodontic clinic program of the Suez Canal University from 2019 – 2023. (2) The cases were randomly numbered as they were collected from the unidentified respective treating orthodontist. (3) Availability of pre-treatment records without being damaged. Pre-treatment dental study models with bite registration (wax bite), The lateral cephalogram and the radiographs had to be of a quality adequate to ensure clearly identifiable landmarks. **Exclusion**

criteria were as follows: (1)Lack of completepretreatment records. (2)Dental study models with broken teeth (3) Radiographic records with errors which will affect the measurement and scoring.

Grouping of the sampleStudy design:

The obtained pretreatment records were assessed according to the ABO's DI,the sample was divided into three groups**.**

Group 1: Low complexity– total DI score 10 points or less,

Group 2: Moderate complexity – total DI scorebetween 10 and 26 points,

Group 3: High complexity – total DI score 26 points or greater.

Investigation and measurements:

The obtained pretreatment records were assessed according to the ABO's DI. Each case started with a DI score of 0, to which the sum of deducted points from the evaluation of casts, cephalometric and panoramic radiograph was added. The measurement methods and scoring of each DI component as follows(7)(Table 1):

A. Step 1: Clinical linear measurements on pre-treatment casts:

1) Overjet, 2) Overbite, 3) Anterior openbite, 4)Lateralopenbite, 5) Crowding, 6) Occlusal relationship, 7) Lingual crossbite, 8) Buccal crossbite.

B. Step 2: Radiographic measurement onlateral cephalogram:

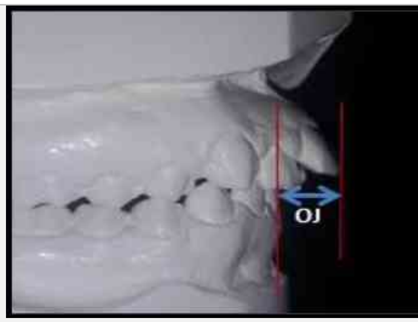
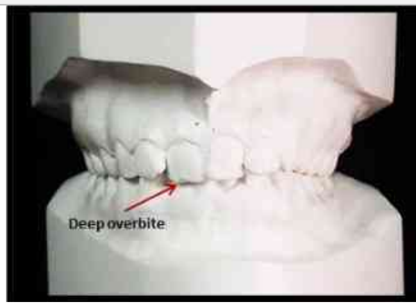
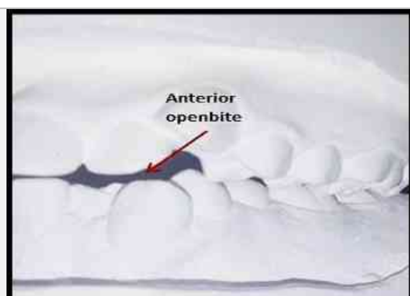
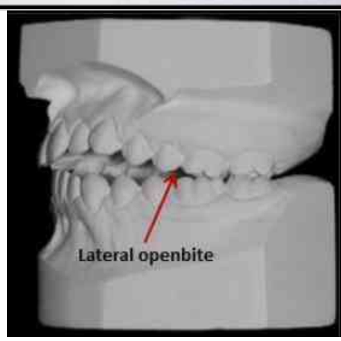
1) ANB angle, 2)SN-MP angle, 3) IMPA

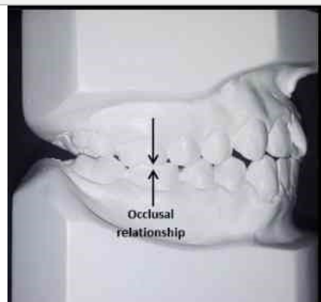
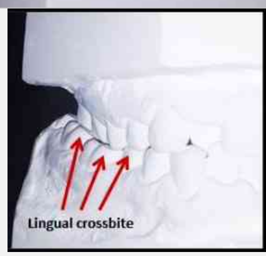
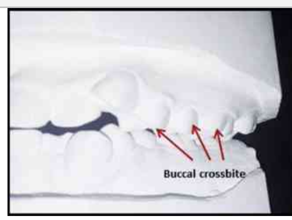
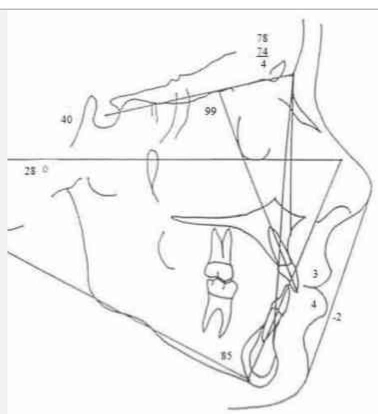
C. Step 3: Other:

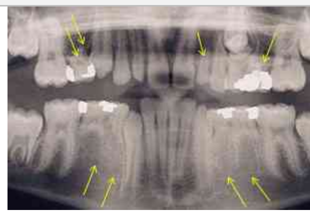
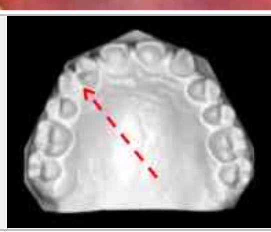
1) Supernumerary teeth, 2) Ankyloses of permanent teeth, 3) Anomalous morphology, 4) Impactions, 5) Missing teeth, 6) Spacing, 7) Midline maxillary diastemata, 8) Tooth transposition, 9) Midline discrepancy, 10) Skeletal asymmetry (treated non-surgically), 10) Additional treatment complexities.

Table 1. Description of the measurement methods and scoring of each DI component.

Occlusal trait	Illustration	Method of measurement	DI scoring scale

Overjet: anterior posterior relationship of upper and lower incisors		clinically by ABO gauge	(1) point: if 0 mm. (edge to edge) (0) point: if 1 - 3 mm. (2) points: if 3.1 - 5 mm. (3) points: if 5.1 – 7 mm. (4) points: if 7.1 – 9 mm. (5) points: if > 9 mm. (1) point. Per mm. per tooth: if negative overjet.
Overbite: vertical overlap of those antagonist incisors which present the greatest discrepancy		clinically by ABO gauge	(0) point: if 0 - 3 mm. (2) points: if 3.1 - 5 mm. (3) points: if 5.1 - 7 mm. (5) points: if impinging (100%) overbite.
Anterior openbite: non- contact of anterior teeth		clinically by ABO gauge	(1) point: if 0 mm. (edge to edge) per tooth, then (2) points. per mm. per tooth.
Lateral openbite: non-contact of teeth distal to the canines		clinically by ABO gauge	(2) points. per mm. of open bite for each tooth.
Crowding: more crowded arch only recorded		clinically by ABO gauge	(1) point: if 0 - 3 mm. (2) points: if 3.1 - 5 mm. (4) points: if 5.1 - 7 mm. (7) points: if > 7mm.

Occlusal relationship: Angle Classification (CI, CII, CIII)		clinically (Angle's molar classification)	(0) point: if class I. (2) points: if end on class II or III. (4) points:if full cusp class II or III (1) point Per mm additional if beyond class II or III
Lingual crossbite: reverse buccal relationship of molars and/or premolars		clinically	(1) point: per tooth
Buccal crossbite: linguoversion of lower molars and/or premolars.		clinically	(2) points: per tooth
ANB angle SN-MP angle IMPA		Radiographically	(4) points: if > 5.5 or < -1.5 (1) point: each additional degree --- (0) point: if 27 deg - 37 deg (2) points: per deg > 37 deg (1) point: per deg < 27 deg --- (1) point: per deg > 98 deg
Supernumerary teeth		Radiographically	(1) point: for each

Ankylosis of permanent teeth		Radiographically	(2) points: per tooth
Anomalous Morphology		clinically	(2) points: per tooth
Impaction of teeth (except 3rd molars)		Radiographically	(2) points: per tooth
Missing teeth		Radiographically	(1) point: non-congenital per tooth. (2) points: Congenital per tooth
Midline Discrepancy		clinically	(2) points: for 3 mm or more.
Spacing		clinically	(2) points: for diastema of ≥ than 2.0 mm. (2) points: for generalized spacing per arch in which there is ≥ 0.5 mm of space on both sides of any 4 teeth or more.
Tooth transposition		Clinically or Radiographically	(2) points: for each event.

Skeletal asymmetry (treated non-surgically		Radiographically	(3) points: if present.

Statistical analyses:

Data was fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp) The Kolmogorov-Smirnov test was used to verify the normality of distribution Quantitative data were described using mean, standard deviation. The significance of the obtained results was judged at the 5% level. The used tests were, Kruskal Wallis test For abnormally distributed quantitative variables, to compare between more than two studied groups, and post hoc for pairwise comparisons, Mann-Whitney U For abnormally distributed quantitative variables, to compare between two studied groups, X2: Chi-Square measure of the difference between the observed and expected frequencies of the outcomes of a set of events or variables, and spearman correlation examines whether two variables are correlated with one another or not.

RESULTS

1. **Descriptive statistics of gender within total DI and DI component.**

Regarding the total DI and DI component, there was a statistically non-significant difference between male and female (p=0.588). The mean DI for female is 21.99 (SD 11.40), and 20.84 (SD 11.06) for male.(Table 2)

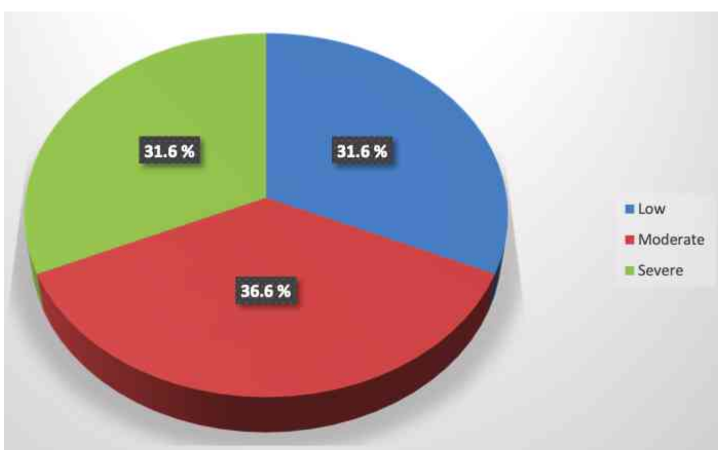
Table 2. Comparison between male and female according to total DI and DI component

Gender	*F*		*M*		*U*	*p*
	Mean	SD	Mean	SD		
DI component						
Overjet	1.78	1.92	1.55	1.704	1433	**0. 465**
Overbite	1.12	1.42	0.97	1.262	1511	**0. 765**
AOB	2.35	6.03	1.84	499	1517	**0. 769**
LOB	0.12	0.71	0.00	000	1501	**0. 234**
Crowding	3.24	2.92	3.76	2.990	1390	**0. 326**
Occlusion	2.21	3.23	1.76	2.917	1383	**0. 280**
LXB	0.49	0.97	0.29	0.694	1433	**0. 342**
BXB	0.43	1.37	0.47	1.704	1483	**0. 451**
Cephalometric	7.23	6.77	6.76	6.748	1483	**0. 670**
Other	2.65	3.21	2.63	2.624	1524	**0. 845**
Total DI	21.99	11.40	20.84	11.06	1462	**0.588**

2. **Descriptive statistics of the total DI and DI component score for the total sample, low, moderate and severe groups.**

there were 38 records with low score (31.6%), 44 records with moderate score (36.6%) and 38 records with severe score (31.6%). Moderate group shows significant difference with low and severe groups, while there was no significant difference between low and severe groups.(Figure1).

Figure1. Descriptive statistics of the total DI and DI component score for the total sample.



3. **Descriptive statistics of the total DI and DI component according to classes.**

there was 64 class I (53.3 %), 39 class II (32.5 %) and 17 class III (14.1 %). Regarding total DI, there was a statistically significant difference between the three classes (p≤ 0.001). Class I showed a significantly lower DI than class II and III. Class II showed a nonsignificant difference with class III. The mean DI was 18.36 (SD 11.00), 24.49 (SD 9.43), and 27.35 (SD 12.57) for class I, II, and III respectively.(Table 3)

Table 3. Comparison between the three groups according to total DI

CLASSES	I		II		III		kw	p
	Mean	SD	Mean	SD	Mean	SD		
Total DI	18.36	11.00	24.49	9.43	27.35	12.57	16.061	≤ 0.001
p0	p1=0.001*, p2=0.012*, p3=1.000							

4. **Multivariate regression analysis of DI parameters that influence the DI score.**

Themultivariate regression analysis revealed that the component DI parameters that exerted the greatest effect on the DI score were the cephalometric parameters ANB, SN-MP and IMPA, crowding, and anterior openbite (AOB), followed by occlusal relation, lingual posterior crossbite, and overbite, while the lowest effect on the DI score were the buccal posterior crossbite, overjet, and lateral openbite. (Table 4)

Table 4. Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	.492	.189		2.603	.011	.117	.867
Overjet	.019	.026	.044	.728	.468	-.032	.070
Overbite	.046	.036	.079	1.266	.208	-.026	.118
AOB	.020	.017	.137	1.178	.241	-.013	.053
LOB	.005	.070	.004	.075	.940	-.134	.145
Crowding	.050	.021	.185	2.433	.017	.009	.091
Occlusion	.031	.025	.122	1.243	.217	-.019	.081
LXB	.086	.050	.096	1.713	.090	-.013	.185
BXB	.036	.030	.067	1.182	.240	-.024	.096
Cephalometric	.044	.017	.372	2.572	.011	.010	.078
Other	.031	.019	.119	1.667	.099	-.006	.069
Total DI	.026	.015	.370	1.734	.086	-.004	.056

Discussion

Analyzing the results:

Regarding the Demographic significance on the total score:

Average DI scores were 21.99 ±11.40 for female patients and 20.84 ±11.06 for male patients. The results showed that there was no statistically significant effect of gender on the total DI and malocclusion complexity (P = 0.588), which coincides with most of the reviewed literature, in agreement with**Schafer et al (2011)**(8), **Parrish et al (2011)**(9), **Bomvana et al (2020)**(10), **Swan et al (2021)**(11).

Regarding the mean DI score of the total sample:

Inthe current study, the mean DI score was 21.4 (SD 11.23). This result comes into agreement with the findings of studies done by other universities. **Deguchi et al (2005)**(12), **Campbell et al (2007)**(13), **Viwattanatipa et al (2016)**(14), **Pyakurel et al (2018)**(6), **Tantipanichkul et al (2019)**(15), and **Mujagic et al (2020)**(16).On the contrary, other studies presented lower means for the total DI scores. **Vu et al (2008)**(17)assessedand evaluate the severity of the pretreatment malocclusion, the results showed a mean of 15.30. This decrease could be due to exclusion of mixed dentition and partially edentulous, which may affect the score of "other" category of DI component. While **Cansunar & Uysal (2014)**(18)performed a study to evaluate the relationship between pretreatment case complexity and orthodontic treatment outcomes. The mean DI score was 16.2. This may be due to the the selection of cases was only for cooperative patients with good oral hygiene without inflammation. Also **Borda et al (2020)**(19)compared the outcomes of clear aligners to fixed appliances. The mean DI was 11.9 (SD 5.3). This could be due to the selection of of samples targeted only patients with mild malocclusionsthat are indicated for clear aligners.

Regarding the percentage of low, moderate, and severe groups:

In the current study, there were 38 records with low score (31.6%), 44 records with moderate score (36.6%) and 38 records with severe score (31.6%). There was a statistically significant difference between the three groups ($p \leq 0.001$).The resulted distribution of cases reflects availability of cases with variety of complexity to the residents, this would ensure that they have exposure to and experience in the management of wide range of case categories. Not to mention that the ABO has suggested to require the residents with two cases of high DI, six cases of moderate range and two in the lower range. **Cangialosi et al (2004)**(2). The application of ABO suggestions appears to be applicable according to the resulted percentages.

Regarding the correlation of the mean DI scores and severity of Angle classification:

In the present study, the malocclusion complexity with in class I was (46.9%) in low group, (35.9%) in moderate group, and (17.2%) in severe group, within class II was (10.3%) in low group, (41.0%) in moderate group, and (48.7%) in severe group, and within class III was

(23.5%) in low group, (29.4%) in moderate group, and (47.1%) in severe group. The mean DI scores were 18.36 (SD 11.00), 24.49 (SD 9.43), and 27.35 (SD 12.57) for patients with Angle's Class I, Class II and Class III malocclusions respectively. These scores were statistically significant ($p \leq 0.001$). Classes showed a significant positive correlation with malocclusion complexity ($p \leq 0.001$). As the Classes increase from I to III, the malocclusion complexity increases.The results were in agreement with a study conducted by **Pyakurel et al** (**2018**)[6].

The correlation and regression analysis of each DI component.

Multivariate regression analysis in present study revealed that the component DI parameters that exerted the greatest effect on the DI score were the cephalometric parameters ANB, SN-MP and IMPA, crowding, and the anterior openbite, followed by occlusal relation, lingual posterior crossbite, and overbite, while the lowest effect on the DI score were the buccal posterior crossbite, overjet, and lateral openbite. Regarding cephalometric analysis, the result in this study showed that the highest effect on DI score was cephalometric, the results were in agreement with the several of the previous studies, as study conducted by **Pulfer et al** (**2009**)[4], **Pyakurel et al (2018)**[6], **Schafer et al (2011)**[8],**Bomvana et al (2020)**[10], and**Swan et al** (**2021**)[11]. Also, the association of the crowding, occlusal relation as found in the presented study is influencing the DI score. The results were consistent with previous studies which also had the samples having cephalometric parameters with higher mean scores. As**Pulfer et al** (**2009**)[4], **Pyakurel et al (2018)**[6]. Concerning the anterior openbite, the current study proved that the openbite highly affects the DI score. Similarly, **Bomvana et al (2020)**[10]found that the anterior openbite did influence the DI score with Africans. This result was not in agreement with**Pyakurel et al** (**2018**)[6] ,and**Parrish et al** (**2011**)[9]. This could be due to the number of cases in the sample who exhibited the trait, and as well as how anterior openbite is scored in DI.There is no definitive limit on points scored for anterior openbite in the DI, as a pointis scored per mm per tooth and this can lead to high scores if all six anterior teeth do not contact with a high metric measurement per tooth, as described by **(American Board of Orthodontics)**[7].Finally, posterior buccal crossbite and lateral open bite in the presented study were one of the DI component that had the least effect on the DI score. The results were in agreement with other study, as **Pulfer et al** (**2009**)[4]found that the lateral openbite has smaller score, and **Schafer et al (2011)**[8] found that the lowest scores were for buccal posterior crossbite. Also a study conducted by **Swan et al** (**2021**)[11]showed that the lowest scores were for lateral open bite and buccal posterior crossbite. The result of the present study and most of the reviewed literature studies have proven that the cephalometric has the greatest effect on DI score than any other components. On the other hand, there is different distribution of the other DI components in the effectiveness on the DI score. This mainly due to the frequency of each component in the sample, and the severity of the points scoring of these components.

Conclusion

1- Patients with ABO-DI low score was (31.6%), moderate score was (36.6%), while (31.6%) of the total sample had a severe ABO-DI score.

2- The ABO-DI of the total sample showed no gender predilection.

3- The distribution of patients among the 3 Angle classifications was 53.3 % for Classes I, 32.5 % for Classes II, and 14.1 % for Classes III. The mean DI scores were 18.36 for Class I, 24.49 for Class II, and 27.35 for patients with Class III malocclusions, also Classes showed a significant positive correlation with malocclusion complexity, As the classes increase from I to III, the malocclusion complexity increases.

4- The component DI parameters that exerted the greatest effect on the DI score were the cephalometric parameters, while the lowest effect on the DI score was the lateral openbite.

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