



CLINICAL RESEARCH:

Application of ABO-CRE Scores to Assess Orthodontic Treatment Outcome

Aplicación del índice CRE en la finalización de los tratamientos de ortodoncia

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ABSTRACT: Adequate treatment finishing is essential for achieving functional, aesthetic, and stable orthodontic outcomes. The American Board of Orthodontics Cast-Radiograph Evaluation (ABO-CRE) provides an objective method for assessing treatment outcome; however, its use in Latin American orthodontic training programs remains limited. The aim of this study was to evaluate orthodontic treatment outcomes in a postgraduate orthodontic program using the ABO-CRE. A retrospective cross-sectional observational study was conducted in an orthodontics program in Bogotá, Colombia. Fifty-nine completed cases (final study models, lateral cephalograms, and panoramic radiographs) were analyzed. Eight components of the ABO-CRE were evaluated. Data were analyzed using ANOVA, chi-square, and binary logistic regression tests, with a significance level set up at $p < 0.05$. Eighty-eight-point one percent of cases obtained an acceptable score (≤ 27 points). Mean scores differed significantly among the orthodontics techniques ($p = 0.0485$), self-ligating (19.92 ± 4.59), standard (22.19 ± 4.09) and MBT (23.59 ± 5.56). The most frequent deficiencies were buccolingual inclination (4.95 ± 2.34), alignment (4.29 ± 2.09), and occlusal relationship (4.17 ± 2.85), while the best results were recorded in interproximal (0.73 ± 1.31) and occlusal contacts (0.76 ± 1.18), which showed the highest levels of compliance. Age and the use of the MBT technique were significantly associated with failing scores ($p < 0.05$). The ABO-CRE proved to be an effective tool for standardizing the evaluation of orthodontic treatment outcome. The findings indicate a high proportion of approved treatment outcomes, despite the absence of clinically meaningful differences among orthodontic techniques, while highlighting the need for improved torque control and greater precision in occlusal finishing.



KEYWORDS: Orthodontics; Fixed orthodontic appliances; Treatment outcome; Dental models; Duration of therapy; Retrospective studies.

RESUMEN: La fase de finalización en ortodoncia es determinante para lograr una oclusión funcional, estética y estable. La American Board of Orthodontics (ABO) desarrolló el índice Cast-Radiograph Evaluation (CRE) como herramienta objetiva para evaluar la calidad de finalización de los tratamientos. Sin embargo, su aplicación en programas académicos latinoamericanos ha sido limitada. El objetivo de este estudio fue evaluar los resultados del tratamiento ortodóncico aplicando la ABO-CRE. Estudio observacional transversal retrospectivo. Se analizaron 59 casos finalizados (modelos de estudio finales, radiografías laterales de cráneo y radiografías panorámicas), en los cuales se evaluaron ocho componentes de la ABO-CRE. Los datos se analizaron mediante ANOVA, chi-cuadrado y regresión logística binaria, con un nivel de significancia de $p < 0,05$. El 88,1 % de los casos obtuvo una puntuación aceptable (≤ 27 puntos). Las puntuaciones medias difirieron significativamente entre las técnicas ortodóncicas ($p = 0,0485$): autoligado ($19,92 \pm 4,59$), estándar ($22,19 \pm 4,09$) y MBT ($23,59 \pm 5,56$). Las deficiencias más frecuentes fueron la inclinación vestibulolingual ($4,95 \pm 2,34$), el alineamiento ($4,29 \pm 2,09$) y la relación oclusal ($4,17 \pm 2,85$), mientras que, los mejores resultados se registraron en los contactos interproximales ($0,73 \pm 1,31$) y oclusales ($0,76 \pm 1,18$), que mostraron los mayores niveles de cumplimiento. La edad y el uso de la técnica MBT se asociaron significativamente con puntuaciones no aprobatorias ($p < 0,05$). La ABO-CRE demostró ser una herramienta eficaz para estandarizar la evaluación de los resultados del tratamiento ortodóncico. Los hallazgos indican una alta proporción de resultados de tratamiento aprobados y resaltan la necesidad de mejorar el control del torque y de lograr mayor precisión en la finalización oclusal.

PALABRAS CLAVE: Ortodoncia; Aparatos ortodóncicos fijos; Resultado del tratamiento; Modelos dentales; Duración de la terapia; Estudios retrospectivos.

INTRODUCTION

The finishing phase is a critical stage of orthodontic treatment, during which final adjustments are made to achieve optimal aesthetic, functional, and stable occlusal outcomes. Careful finishing contributes to treatment stability, periodontal health, and patient satisfaction, distinguishing acceptable results from those of the highest clinical quality (1).

To provide an objective assessment of treatment outcomes, the American Board of Orthodontics (ABO) introduced in 1998 the Objective Grading System (OGS), currently known as the Cast-Radiograph Evaluation (CRE). This standardized system evaluates post-treatment quality

using study models and panoramic radiographs across eight criteria: alignment, marginal ridges, buccolingual inclination, overbite, overjet, occlusal relationship, occlusal contacts, interproximal contacts, and root angulation (2-5).

Previous studies have emphasized that the assessment of orthodontic treatment outcomes should incorporate both functional and aesthetic parameters. Features such as dental midline position and smile arc have a direct impact on facial harmony and the overall perception of treatment quality (6). Nevertheless, finishing discrepancies may persist even in cases that achieve satisfactory scores according to the ABO criteria. The most reported deficiencies include residual rotations, inadequate buccolingual inclinations, and marginal

ridge discrepancies. To minimize these shortcomings, several authors have recommended the use of structured finishing protocols and clinical evaluation tools to improve treatment quality and promote greater standardization in orthodontic practice (6, 7). In addition, studies using ABO-OGS have reported comparable occlusal outcomes for treatments performed with straight-wire and conventional appliance systems, although conventional techniques have generally been associated with longer treatment durations (8). Orthodontic training programs have implemented various quality assessment indices to monitor and improve treatment outcomes, underscoring the importance of standardized evaluation protocols. Most studies evaluating orthodontic treatment outcomes in academic settings have employed the ABO-OGS as a standardized measure. For example, one study reported that only 50% of cases met the established quality standards and found that greater initial malocclusion complexity was associated with poorer final scores and longer treatment duration (4). Similarly, other studies conducted in academic settings have reported favorable treatment outcomes among patients treated by orthodontic residents, supporting the effectiveness of structured training and supervision protocols (4, 9).

Several studies have compared the quality of orthodontic treatment outcomes between university-based programs and private practices, reporting no significant differences in overall ABO-OGS scores. However, greater variability in outcomes has been observed in academic settings, possibly reflecting differences in resident experience and levels of clinical training (10). Similarly, other investigations have found comparable rates of acceptable treatment outcomes between university clinics and private practices. Although total ABO-OGS scores did not differ significantly, university-based treatments demonstrated better performance in buccolingual inclination and marginal

ridge criteria, whereas private practice treatments achieved more favorable root angulation scores. Furthermore, bracket type, age, and sex were not identified as significant factors associated with treatment quality (11).

Although the ABO-CRE index provides a standardized framework for assessing the quality of orthodontic treatment outcomes, its implementation in postgraduate orthodontic training programs remains limited, particularly in Latin America. Consequently, evidence regarding treatment completion outcomes in these educational settings is scarce. This study seeks to expand the available evidence from Latin American postgraduate orthodontic programs by evaluating factors associated with orthodontic treatment outcomes.

The aim of this study was to evaluate orthodontic treatment outcomes in a postgraduate orthodontic program using the American Board of Orthodontics Cast-Radiograph Evaluation (ABO-CRE) index.

MATERIALS AND METHODS

A retrospective cross-sectional observational study was conducted between 2021 and 2024 in the Orthodontics and Dentofacial Orthopedics program at the CIEO University Foundation (UniCIEO). This study was approved by the UniCIEO Research Ethics Committee (Aval 186/ minute 83) in accordance with the Declaration of Helsinki.

All treatments were performed by second- and third-year residents in the postgraduate orthodontics program under a standardized supervision protocol. Diagnosis and treatment planning were reviewed and approved by three orthodontic faculty members, with interdisciplinary input from periodontics and speech therapy specialists when indicated. All clinical appointments and procedu-

res were supervised by a faculty orthodontist to ensure adherence to institutional protocols and consistency in patient management.

A non-probability convenience sampling approach was used to select the records of patients who had completed orthodontic treatment and had complete documentation available. Eligible records included initial and final study models with complete permanent dentition up to the second molars, as well as corresponding lateral cephalometric and panoramic radiographs in digital STL format. Exclusion criteria comprised patients with indications for orthognathic surgery, those requiring oral rehabilitation treatment, individuals with a history of previous orthodontic treatment, and cases with missing or inadequate-quality study models or radiographic records.

The sample size was calculated using Epidat 4.2 software (Xullo 2016; Consellería de Sanidade, Xunta de Galicia, Spain; Pan American Health Organization; CES University, Colombia). Based on the study by Djeu *et al.* (12), assuming a standard deviation of 11.73 points for the ABO-OGS score, a 95% confidence level, a precision of 3%, and an estimated population of 500 patients, the minimum required sample size was 50 subjects.

The primary outcome was orthodontic treatment quality, assessed using the American Board of Orthodontics Cast-Radiograph Evaluation (ABO-CRE) index (5) and a standardized measuring gauge. The ABO-CRE evaluates seven components on the final study models and one component on the final panoramic radiograph. The model-based criteria included alignment, marginal ridges, buccolingual inclination, occlusal relationship, occlusal contacts, overjet, and interproximal contacts, whereas root angulation was assessed on the panoramic radiograph.

ABO-CRE scores were classified as approved (≤ 27 points) or non-approved (> 27 points). Additionally, cases were categorized according to treatment quality as excellent (≤ 20 points), acceptable (21-27 points), or less than acceptable and > 27 points, following previously established criteria (5, 7).

Measurements were performed by two calibrated examiners. Reproducibility was assessed using 18 study models and radiographs, which were re-evaluated after a two-week interval. An acceptable measurement error of ± 2 points on the ABO-CRE was established. Random error was assessed using Dahlberg's formula, whereas systematic error was evaluated with the Houston paired t-test.

Additionally, information on dental and skeletal malocclusion, orthodontic technique, treatment duration (months), sex, and final archwire type was extracted from the patients' records.

STATISTICAL METHODS

Data management and quality control were performed in Microsoft Excel 365. Statistical analyses were conducted using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). Qualitative variables were summarized as frequencies and percentages. Quantitative variables were described using means and standard deviations or medians and interquartile ranges, according to data distribution. Normality was assessed using the Shapiro-Wilk test.

Comparisons among orthodontic techniques were performed using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test for normally distributed variables, and the Kruskal-Wallis test for non-normally distributed

variables. Associations between qualitative variables and orthodontic techniques were evaluated using Pearson's chi-square test.

Finally, a multivariable binary logistic regression model was constructed using the enter method. Variables that showed statistical significance in the bivariate analysis were included in the model. Model fit was assessed using the Hosmer–Lemeshow goodness-of-fit test and Nagelkerke's R^2 . To minimize the risk of overfitting, the sample size met the requirement of at least 10 events per variable ($10(k+1)$), where k represents the number of independent variables included in the model. Statistical significance was set at $p < 0.05$, and 95% confidence intervals (95% CI) were calculated for all relevant estimates.

RESULTS

The intraexaminer error was 1.25 points and the interexaminer error was 1.83 points. No significant systematic error was detected ($p \geq 0.10$). A total of 180 patient records were screened for eligibility. Of these, 121 were excluded for the following reasons: absence or inadequate quality of the initial and final study models, lateral cephalometric radiographs, or panoramic radiographs in STL digital format ($n=58$); incomplete permanent dentition in the initial or final records, included extraction treatment protocols ($n=16$); indication for orthognathic surgery ($n=11$); need for oral rehabilitation treatment ($n=13$); and history of previous orthodontic treatment ($n=25$). Consequently, 59 records met the eligibility criteria and were included in the final analysis.

Male patients predominated in the sample, as did skeletal Class I, canine Class II, and molar Class I malocclusions. The mean age was 26.53 years ($SD=8.75$), and the mean treatment duration

was 19.62 months ($SD=7.53$). Significant differences in final archwire type were observed among techniques ($p < 0.05$), with 0.019×0.025-inch stainless steel archwires used more frequently in the MBT and self-ligating groups and 0.016×0.022-inch archwires in the Standard group (Table 1).

The mean ABO-CRE score was 21.59 ($SD=4.94$). The highest mean score was observed in the MBT group (23.59 ± 5.56), with significant differences among techniques (ANOVA: $F=3.214$, $p=0.0485$) (Table 2). Post hoc analysis (Tukey HSD) showed a significant difference between the MBT and self-ligating techniques ($p=0.043$) (Table 3). Among the ABO-CRE components, buccolingual inclination, alignment/rotations, and occlusal relationship had the highest scores, whereas interproximal and occlusal contacts had the lowest scores (Table 2).

A total of 88.1% of cases achieved an approved outcome (ABO-CRE score ≤ 27 ; 95% CI: 79.88-93.39). The highest proportion of approved cases was observed in the self-ligating group (96.2%; 95% CI: 88.76-100), followed by the Standard (93.8%; 95% CI: 81.89-100) and MBT groups (70.6%; 95% CI: 48.93-92.25), with significant differences among techniques ($p=0.032$) (Table 4, Figure 1). The self-ligating technique showed the highest proportion of excellent outcomes (ABO-CRE score ≤ 20 ; 42.3%), whereas the MBT technique showed 29.4% (Table 4).

In the multivariable logistic regression analysis, age ($OR=1.110$; 95% CI: 1.002-1.230; $p=0.045$) and the MBT technique ($OR=24.127$; 95% CI: 1.106-526.180; $p=0.043$) were associated with non-approved ABO-CRE outcomes (Table 5). The model fit the data adequately (Hosmer–Lemeshow test, $p=0.940$) and showed moderate explanatory power (Nagelkerke's $R^2=0.474$).

Table 1. Sample characteristics (n=59).

Variable	MBT n=17 n (%)		Standard n=16 n (%)		Self-ligating n=26 n (%)		Total n=59 n (%)		P value	
Sex										
Male	8 (47.1)		10 (62.5)		19 (73.1)		37 (62.7)		0.226†	
Female	9 (52.9)		6 (37.5)		7 (26.9)		22 (37.3)			
Skeletal classification										
Class I	9 (52.9)		10 (62.5)		12 (46.2)		31 (52.5)		0.131†	
Class II	2 (11.8)		5 (31.3)		10 (38.5)		17 (28.8)			
Class III	6 (35.3)		1 (6.3)		4 (15.4)		11 (18.6)			
Canine classification										
Class I	6 (35.3)		2 (12.5)		8 (30.8)		16 (27.1)		0.470†	
Class II	8 (47.1)		7 (43.8)		10 (38.5)		25 (42.4)			
Class III	0 (0.0)		1 (6.3)		1 (3.8)		2 (3.4)			
Class II division	2 (11.8)		6 (37.5)		7 (26.9)		15 (25.4)			
Class III division	1 (5.9)		0 (0.0)		0 (0.0)		1 (1.7)			
Molar classification										
Class I	7 (41.2)		8 (50.0)		10 (38.5)		25 (42.4)		0.156†	
Class II	1 (5.9)		1 (6.3)		3 (11.5)		5 (8.5)			
Class III	3 (17.6)		0 (0.0)		4 (15.4)		7 (11.9)			
Class II division	0 (0.0)		3 (18.8)		0 (0.0)		3 (5.1)			
Class III division	6 (35.3)		4 (25.0)		9 (34.6)		19 (32.2)			
Upper final arch										
SS 0,019 x 0,025	16 (94.1)		1 (6.3)		21 (80.8)		38 (64.4)		0.000†	
SS 0,016 x 0,022	0 (0)		13 (81.3)		0 (0)		13 (22)			
Australian 0,018	1 (5.9)		2 (12.5)		0 (0)		3 (5.1)			
NiTi 0,019 x 0,025	0 (0)		0 (0)		3 (11.5)		3 (5.1)			
Tanzo 0,019 x 0,025	0 (0)		0 (0)		1 (3.8)		1 (1.7)			
Hi Tech 019 x 0,025	0 (0)		0 (0)		1 (3.8)		1 (1.7)			
Lower final arch										
SS 0,019 x 0,025	15 (88.2)		1 (6.3)		19 (73.1)		35 (59.3)			
SS 0,017 x 0,025	0 (0)		0 (0)		1 (3.8)		1 (1.7)			
SS 0,016 x 0,022	0 (0)		12 (75)		0 (0)		12 (20.3)			
Australian 0,018	2 (11.8)		3 (18.8)		0 (0)		5 (8.5)			
NiTi 0,019 x 0,025	0 (0)		0 (0)		4 (15.4)		4 (6.8)			
Tanzo 0,019 x 0,025	0 (0)		0 (0)		1 (3.8)		1 (1.7)			
Hi Tech 0,018 x 0,025	0 (0)		0 (0)		1 (3.8)		1 (1.7)			
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)		
Age	24.04 (9.61)	23.96 (8.16)	26.82 (12.50)	23.45 (15.01)	26.53 (8.75)	26.49 (11.47)	26.53 (8.75)	24.55 (11.21)	0.408‡	
Treatment time (months)	23.43 (9.76)	20.80 (16.40)	19.17 (7.33)	18.47 (7.52)	19.62 (7.53)	19.58 (10.27)	19.62 (7.53)	19.57 (10.27)	0.396‡	

SD: Standard Deviation. IQR: Interquartile range. SS: Stainless Steel. * $p < 0.005$. † Chi-square test. ‡ Kruskal-Wallis's test.

Table 2. Comparison of CRE variable scores by orthodontic technique.

Variable	MBT n=17		Standard n=16		Self-ligating n=26		Total n=59		P value
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
Alignment	4.82 (2.21)	4.00 (2.00)	4.50 (2.07)	3.50 (3.00)	3.81 (2.00)	3.5 (3.00)	4.29 (2.09)	4 (3.00)	0.290‡
Marginal ridge	3.47 (1.97)	3.00 (2.00)	4.25 (1.61)	4.00 (2.00)	3.58 (1.79)	3.00 (3.00)	3.73 (1.8)	4 (3.00)	0.272‡
Buccolingual inclination	5.59 (2.21)	6.00 (3.00)	4.00 (1.90)	4.00 (2.50)	5.12 (2.55)	5.00 (3.00)	4.95 (2.34)	5 (3.00)	0.132§
Overjet	1.12 (0.93)	1.00 (2.00)	0.75 (0.77)	1.00 (1.00)	0.92 (0.93)	1.00 (2.00)	0.93 (0.89)	1 (2.00)	0.529‡
Occlusal contacts	0.76 (1.30)	0.00 (1.00)	1.00 (1.75)	1.00 (2.00)	0.62 (1.13)	0.00 (1.00)	0.76 (1.18)	0 (1.00)	0.293‡
Occlusal relationship	4.94 (3.07)	4.00 (4.00)	4.25 (3.11)	3.50 (5.50)	3.62 (2.52)	4.00 (3.00)	4.17 (2.85)	4 (5.00)	0.448‡
Interproximal contacts	0.65 (1.00)	0.00 (1.00)	1.13 (1.67)	1.00 (1.00)	0.54 (1.24)	0.00 (1.00)	0.73 (1.31)	0 (1.00)	0.259‡
Root Angulation	2.24 (1.56)	2.00 (2.00)	2.31 (1.49)	2.00 (2.50)	1.73 (1.19)	2.00 (2.00)	2.03 (1.39)	2 (3.00)	0.454‡
CRE Score	23.59 (5.56)	24.00 (10.00)	22.19 (4.09)	22.00 (5.00)	19.92 (4.59)	21.00 (6.00)	21.59 (4.94)	21 (7.00)	0.048§*

*p<0.005. ‡ Kruskal-Wallis's test. § ANOVA.

Table 3. Post hoc comparisons (Tukey HSD) of CRE scores between orthodontic techniques.

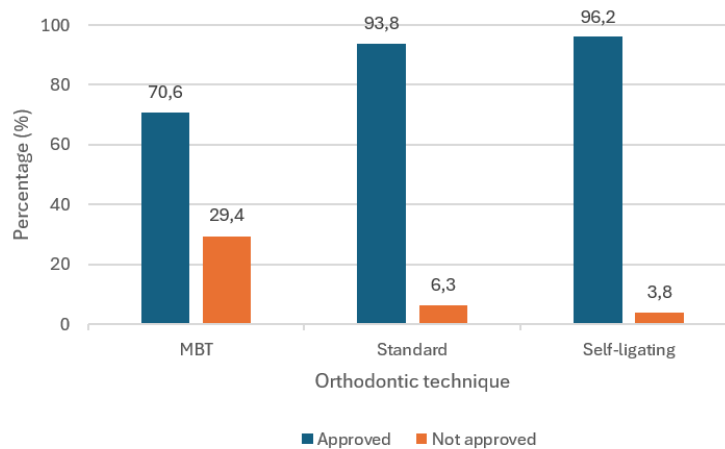
Comparison	Mean difference (SD)	IC 95% (Lower-Upper)	P value
MBT vs. Standard	1.401 (1.659)	(-2.59; 5.39)	0.677
MBT vs. Self-ligating	3.665 (1.486)	(0.09; 7.24)	0.043*
Standard vs. Self-ligating	2.264 (1.513)	(-1.38; 5.91)	0.300

SD: Standard Deviation. * p<0.005. Tukey's post hoc test.

Table 4. Comparison of CRE classification by orthodontic technique.

Orthodontic technique	MBT n=17	Standard n=16	Self-ligating n=26	Total n=59	P value
	n (%)	n (%)	n (%)	n (%)	
Approved					
Yes	12 (70.6)	15 (93.8)	25 (96.2)	52 (88.1)	0.032*
No	5 (29.4)	1 (6.3)	1 (3.8)	7 (11.9)	
Classification					
Excellent	5 (29.4)	4 (25)	11 (42.3)	20 (33.9)	0.076
Acceptable	7 (41.2)	11 (68.8)	14 (53.8)	32 (54.2)	
Less than acceptable	5 (29.4)	1 (6.3)	1 (3.8)	7 (11.9)	

*p <0.05. Chi-square test.



Chi-square test, $p = 0.032$.

Figure 1. Distribution of approved and not approved CRE classifications by orthodontic technique.

Table 5. Binary logistic regression analysis of the association between CRE scores and predictor variables (approved/not approved outcome).

Model	OR (IC 95%)	P value
Female sex	0.117 (0.010; 1.311)	0.082
Age	1.110 (1.002; 1.230)	*0.045
Orthodontic technique		
MBT	24.127(1.106; 526.180)	*0.043
Standard	1.436(0.055; 37.186)	0.827
Treatment time (months)	1.052(0.939; 12.203)	0.378
Skeletal classification		
Class I	0.929(0.071; 12.203)	0.955
Class II	0.273(0.014; 5.372)	0.393

Binary logistic regression (enter method). * $p < 0.05$. Reference categories: approved classification, skeletal Class III, male sex, and self-ligating orthodontic technique. OR: odds ratio. 95% CI: 95% confidence interval.

DISCUSSION

The aim of this study was to evaluate orthodontic treatment outcomes in a postgraduate orthodontics program using the ABO-CRE. The findings showed that 88.1% of cases achieved an approved outcome, with most cases classified as acceptable or excellent according to the ABO-CRE criteria. Significant differences were observed among orthodontic techniques, with better performance in cases treated with self-ligating and

standard techniques than with the MBT technique. These findings are consistent with previous studies reporting variations in treatment outcomes according to appliance systems and finishing protocols. However, because case complexity was not evaluated in the present study, these differences should not be interpreted as being attributable solely to the orthodontic technique. Other factors, including case complexity, operator experience, treatment planning, and finishing procedures, may also have contributed to the observed outcomes (7).

In the present study, the mean ABO-CRE score corresponded to an acceptable outcome according to ABO criteria (5-7). This result was better than those reported in several previous studies conducted in university-based orthodontic programs, where higher mean scores have generally been observed (4,8,13). Similarly, a systematic review of the literature reported a pooled mean ABO-OGS score higher than that observed in the present study (14).

Although some studies conducted in non-academic settings have reported lower scores, suggesting more favorable outcomes (1,8), differences among studies may reflect variations in clinical setting, case selection, treatment protocols, operator experience, and educational objectives.

In postgraduate orthodontic programs, treatment is performed within structured training and supervision protocols; however, factors such as resident experience, case complexity, and academic time constraints may influence treatment outcomes. Therefore, differences in ABO-CRE scores should be interpreted within the broader clinical and educational context rather than being attributed solely to the orthodontic technique used (10,11). Furthermore, 88.1% of the cases achieved an approved score, a proportion that appears higher than that reported in several previous studies conducted in academic settings, where lower rates of acceptable outcomes have been described (1,4).

The highest ABO-CRE scores in the present study were observed in the criteria of buccolingual inclination, alignment/rotations, and occlusal relationship, indicating that these were the areas with the greatest deficiencies at the end of treatment. This result is consistent with findings from other studies, where these components are frequently identified as problematic (8,13). Furthermore, a study comparing treatments with and without extractions also noted that occlusal

relationship was one of the criteria with significant differences between the groups, highlighting its complexity in finishing (1). The American Board of Orthodontics (ABO) has historically recognized that buccolingual inclination and alignment of the second molars are the most common errors observed in clinical examinations (5). The fact that these variables have the highest scores in our research reinforces the notion that torque control, rotation correction, and final anteroposterior adjustment continue to be the most significant challenges in achieving excellent results in orthodontic practice. Tooth morphology, torque, and precision in bracket cementation are crucial factors that determine the success of the orthodontic finishing phase (15). Coronal morphological variations such as differences in vestibular convexity, crown length, and root inclination can significantly alter torque expression and thus the quality of interocclusal relationships. These morphological variations can lead to residual rotations or poor torque control, especially in teeth with irregular or asymmetrical anatomies (16). The correct expression of torque depends not only on bracket design and wire rigidity, but also on the relationship between arch size and slot dimensions. Recent studies have shown that minimal errors in the vertical position or angulation of the bracket can decrease the effective torque expression, compromising final root inclination and post-treatment stability (17). In this context, precision of cementation plays a decisive role, and the clearance between the slot and the wire directly influences the treatment outcome. Recent research shows that deviations of less than 0.5 mm in the cementation position can generate clinically significant differences in final positioning, affecting the interincisal relationship, occlusal plane leveling, and arch coordination (18).

The components of the ABO-CRE that had the lowest scores, indicating better outcome, were interproximal contacts and occlusal contacts. This finding contrasts with the results of a study conducted in China, where interproximal contacts,

along with occlusal relationships, overbite, and alignment, were identified as key predictors of treatment quality, suggesting that deficiencies are commonly found in these areas (19). In contrast, the ABO has pointed out that inadequate occlusal contacts, especially between the second molars, are one of the most common problem areas identified in the cases evaluated (5). The low scores for these parameters obtained in our study suggest a high level of occlusal adjustment and the establishment of adequate posterior intercuspation, areas that often represent a significant challenge during orthodontic treatment completion. However, the clearance between the bracket slot and the finishing archwire may decrease three-dimensional control during final adjustments. In this context, the selection of the bracket system, the type of archwire, and the material characteristics, such as rigidity or coating, are decisive factors in the quality of the finish (20).

Age and the MBT technique were associated with failing outcomes in the multivariable analysis; however, these associations should be interpreted cautiously given the wide confidence intervals, the limited number of failing cases and the absence of baseline case complexity assessment. Further studies are needed to confirm these findings. This finding is interesting when contrasted with other studies, which have not established a clear superiority of one technique over another in terms of occlusal results (7). Therefore, the differences observed among techniques should be interpreted within the broader clinical and educational context in which treatment was delivered. Because case complexity was not assessed, these differences cannot be attributed solely to the appliance system and may have been influenced by factors such as operator experience, treatment planning, and finishing procedures. By contrast, an Ecuadorian study found an approved rate of 88% in cases treated with self-ligating brackets compared to 12% in cases treated with conventional ligating

brackets, with the type of appliance identified as a determining factor (1,21,22).

The multivariate logistic regression model showed that age was associated with higher ABO-CRE score. Several studies have shown that the patient's age can significantly influence treatment outcome due to the biological response to treatment. In young patients, the response of bone and periodontal tissue adaptation facilitates tooth movement and a more predictable treatment outcome (23). Conversely, in adults, reduced bone remodeling and increased cortical density can slow down the biological response, prolonging treatment time and making it difficult to achieve fine occlusal adjustments (24). Kiyamehr *et al.* (25) and Gyasudeen *et al.* (9) reported that age at the start of treatment correlates with the duration and quality of the finish, noting that younger patients tend to achieve more efficient and stable results.

Another factor that has been shown to have an impact on treatment is the finishing archwire used. The rigidity of the wire, the material it is made of, and the dimensions of both the archwire and the slot are key factors in determining the degree of prescription expression and control during treatment completion. Comparative studies have shown that brackets with a .018 slot have less clearance between the archwire and the slot, which improves torque expression and root control during the detailing phase (26). In contrast, brackets with .022 slots, although offering greater versatility in arch selection, may require greater clinical refinement to compensate for the loss of control resulting from the increased play between the wire and the slot (27). Kolge *et al.* (28) reported that the mechanical properties and dimensional accuracy of 0.019×0.025" steel archwires are crucial for ensuring controlled tooth movement and faithful expression of the bracket prescription, while avoiding deformations that may compromise the finish. Likewise, studies on dimensional

changes in the arches during the finishing phase have shown that the use of rigid stainless steel archwires maintains the shape of the arch and improves post-treatment stability (28,29). In the present study, a preference was observed for the use of stainless steel archwires, in gauges of 0.019 x 0.025" for the MBT and self-ligating techniques and 0.016 x 0.022" for the standard technique, in both the upper and lower arches. This trend shows a preference for stiffer materials to optimize three-dimensional control and enhance prescription expression in the final stage. Taken together, these findings confirm that the incorporation of a 0.019x0.025" steel archwire as the final stage of the treatment sequence contributes decisively to achieving a high-quality orthodontic finish (23).

Several limitations should be considered when interpreting the findings. First, baseline case complexity was not assessed using a standardized instrument such as the ABO-DI; therefore, treatment outcomes could not be adjusted for initial malocclusion severity. Additionally, the use of convenience sampling, the single-center design, the relatively small subgroup sample sizes, and the limited number of failing cases may restrict the generalizability of the findings and reduce statistical power. Potential confounding related to treatment planning, operator experience, and extraction versus non-extraction protocols may have influenced the results, as these variables were not assessed. However, all treatments were conducted within a standardized and supervised clinical framework.

ABO-CRE provided a structured framework for assessing orthodontic treatment outcomes and identifying specific areas requiring improvement. Although most treatments achieved acceptable outcomes, buccolingual inclination, alignment, and occlusal relationship were the components with

the highest scores, suggesting that these aspects may require additional attention during orthodontic training and the finishing phase of treatment.

Based on the present findings, future research should incorporate standardized measures of baseline case complexity, such as the ABO Discrepancy Index, to better assess their potential association with orthodontic treatment outcomes. Future research should also consider incorporating overbite assessment, given its potential relationship with functional, dental, and temporomandibular outcomes, as well as its influence on overall treatment results. In addition, factors associated with root angulation, including root anatomy, adjacent anatomical structures, and bracket prescription because of their potential impact on final tooth position. Finally, the integration of digital assessment methods may enhance the accuracy and objectivity of treatment outcome evaluation.

CONCLUSIONS

The study showed that 88.1% of the evaluated cases achieved an approved outcome according to the ABO-CRE criteria, reflecting an overall satisfactory level of orthodontic treatment completion. The lowest scores were observed for interproximal and occlusal contacts, whereas buccolingual inclination, alignment/rotations, and occlusal relationship represented the main areas requiring improvement during the finishing phase. These findings highlight the importance of enhancing torque control, rotation correction, and anteroposterior adjustments to optimize treatment outcomes. Although differences in ABO-CRE scores were observed among orthodontic techniques, these findings should be interpreted with caution, as treatment outcomes may also be influenced by factors not evaluated in this study, including case complexity and operator-related variables.

STATEMENTS

AUTHOR CONTRIBUTION STATEMENT: Conceptualization and Design, J.C.C.V. and J.P.B.C.; Literature Review, J.E.M.P. and A.F.R.R.; Methodology and Validation, M.T.A.F. and J.P.B.C.; Formal Analysis, J.P.B.C. and E.A.I.P.; Investigation and Data Collection, J.E.M.P. and A.F.R.R.; Resources, J.E.M.P. and A.F.R.R.; Data Analysis and Interpretation, J.C.C.V., M.T.A.F., J.P.B.C., E.A.I.P.; J.E.M.P. and A.F.R.R.; Writing – Original Draft Preparation, J.C.C.V., M.T.A.F., J.P.B.C., E.A.I.P., J.E.M.P. and A.F.R.R.; Writing – Review & Editing, J.C.C.V., M.T.A.F., J.P.B.C., E.A.I.P., J.E.M.P. and A.F.R.R.; Supervision, M.T.A.F. and J.P.B.C.; Project Administration, J.E.M.P. and A.F.R.R.; Funding Acquisition, J.E.M.P. and A.F.R.R.

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