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Research Article

HOW RELIABLE IS THE AMOUNT OF INTERPROXIMAL REDUCTION CLINCHECK SOFTWARE RECOMMENDS?

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ABSTRACT

Objective: This study was conducted to evaluate the reliability of Bolton analysis results obtained with ClinCheck software and the interproximal reduction (IPR) ratios the software recommends.

Materials and Methods: From the Invisalign® clear aligner system database, 120 individuals were divided into three groups according to Angle classification: dental class I (n=43), dental class II (n=49), and dental class III (n=28) malocclusions. The Bolton analysis data and the IPR amounts determined by Align Technology's digital treatment planning interface, ClinCheck, were evaluated separately for the maxilla and mandible for each individual. A discrepancy was defined as the condition in which the Bolton ratio the software determined and the suggested IPR amount for the anterior ratio and the overall ratio exceeded 2 mm. The average anterior Bolton ratio and suggested anterior Bolton ratio, along with the total Bolton ratio and suggested total Bolton ratio for all individuals, were compared using Cronbach's alpha.

Results: It was determined that the average suggested anterior Bolton ratio for individuals with class I malocclusion was higher than that for individuals with other malocclusions (p=0.008). Cronbach's alpha for the anterior Bolton ratio and the suggested anterior Bolton ratio was 0.131 whereas the overall ratio and the suggested overall Bolton ratio value were determined to be 0.41. Both values are defined as indicating weak reliability.

Conclusion: A weak reliability relationship was detected between the Bolton values obtained with the ClinCheck software and the IPR suggestions provided in treatment planning.

Keywords: Invisalign, clincheck software, interproximal reduction, bolton

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INTRODUCTION

In clear aligner treatments, software that facilitates digital treatment planning for diagnosis and treatment purposes is utilized (1). Each clear aligner manufacturer employs its own software under various names (2). Currently, the widely preferred company Invisalign® (Align Technology, San Jose, Calif) uses ClinCheck™ (Align Technology) (1,2). This software offers clinicians model analyses used for diagnostic purposes before treatment planning, such as tooth movement charts, space analysis, initial and final overjet, overbite, and Bolton analysis (3).

Three-dimensional models obtained with scanners give near-real results in linear measurements or analyses and are reliably used (4–6). Meade et al. (7) stated that the initial overjet and overbite values in ClinCheck can be reliably used. However, Martin et al. (8) mentioned that although the mesiodistal widths of teeth, excluding the molars, are acceptable, the results of the Bolton analysis are not accurate and acceptable, especially for individuals with excess material in the mandibular teeth. Shailendran et al. (9) also indicated that the mesiodistal widths of teeth obtained with ClinCheck are recorded as smaller, and attention should be paid to this issue in Bolton analysis ratios and treatment planning.

In the studies, it was reported that gender had no effect on the bolton ratio, while significant differences were found in the bolton ratios of individuals with different dental malocclusions (10,11). Differences in Bolton analysis can lead the clinician to consider different treatment plans. This particularly includes unnecessary or insufficient interproximal reduction (IPR) from the enamel surface, which might result in the planned tooth movement not occurring as well as complications, such as diastema and black triangles after treatment. Fiori et al. (12) stated that in ClinCheck, the IPR process presents the least accurate data, 49% in the maxilla and 42% in the mandible.

In clear aligner treatments, the software used offers the clinician a treatment plan based on the results of the Bolton analysis. This treatment plan may include options such as leaving a diastema or performing an IPR procedure. The initial prescription the clinician requests in their software preferences is also important. Our study was conducted to evaluate the reliability of Bolton analysis results obtained with ClinCheck and the recommended IPR rates for individuals who will undergo treatment planning with the Invisalign system

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(Align Technology, San Jose, Calif). Our study's null hypothesis (H0) is "There is no reliability between the results of the Bolton analysis obtained with digital treatment planning and the treatment plans."

MATERIALS AND METHODS

This retrospective study commenced with the approval of the Non-Invasive Clinical Research Ethics Committee of Van Yüzüncü Yıl University (2023/13-11). All individuals or parents of individuals under 18 who applied to the Orthodontics Department of Van Yüzüncü Yıl University for treatment were informed about the study, and written consent forms were obtained. G*power software (ver. 3.1.9.7; Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) was used to determine the sample size. The total sample size was calculated as minimum 84, based on an effect size (d) of 0.4, a Type I error ($\alpha = 0.05$), and a power value of 90% for the three main groups.

The study included individuals aged 15-35 with permanent dentition and no missing, impacted, or atypically erupted teeth. Excluded were cases with prosthetic restorations, such as crowns or implants affecting mesiodistal width; decay; fillings; enamel defects; more than 6 mm of crowding or polydiastema, crown angulations over 45 degrees; indications for orthognathic surgery; cleft lip and palate or other craniofacial anomalies; and those with incomplete three-dimensional model images in screening scans.

All data used in this study were collected from the database registered with the Invisalign® clear aligner system. Participants were divided into three groups based on Angle's classification: dental class I (n=43), dental class II (n=49), and dental class III (n=28) malocclusion.

For the participants' scans, the iTero Element® (iTero Element 5D, Align Technologies Inc, San Jose, CA, USA) three-dimensional intraoral scanner device by Align Technology was used. Following the sequence in the manufacturer's scanning guide, occlusal, lingual, and buccal surfaces and finally, rotating tooth surfaces were scanned. After patients were scanned with the intraoral scanner device, the created tooth-jaw models, along with a detailed treatment plan, were virtually sent to the Invisalign® laboratory. Each patient's prescription in all three groups was checked to ensure the doctor had given no IPR instructions and that the "as needed" option was selected in the IPR section. Additionally, the clinician determined the necessary treatment package

from Align Technology's Comprehensive (unlimited aligners), Moderate (up to 20 aligners), and Lite packages (up to 14 aligners) based on the type of malocclusion.

As a result of these procedures, the Invisalign® company, using software (Treat) that simulates tooth movements, sent back to the clinician a virtual treatment plan and the Bolton analysis results of individuals and the proposed IPR amounts through the ClinCheckTM program as the initial treatment plan (Figure 1). All data were collected from the initial treatment plan in ClinCheck™, with Bolton analysis data for each individual noted in millimeters separately for the maxilla and mandible in an Excel sheet. Then, the proposed IPR data for the same individual in the tools section of ClinCheck™ program were calculated separately for the maxilla and mandible and added to the Excel sheet. Inconsistencies were noted if the discrepancy between the Bolton analysis determined by the software and the suggested amount of IPR exceeded 2 mm in either the anterior or total ratio (13). All data for this study were used from a single clinician's (..) system, and the same clinician noted necessary calculations in the Excel sheet.

Statistical analysis

Descriptive statistics for the focused attributes were expressed as count, mean, and standard deviation. An ANOVA analysis was conducted to evaluate differences between groups regarding the variables, and the Duncan test was applied for multiple comparisons. The reliability of the anterior Bolton ratio and total Bolton ratio values was tested using Cronbach's alpha reliability scale. The Cronbach's alpha range was considered as follows: excellent reliability for $0.90 \leq \alpha \leq 1$, high reliability for $0.70 \leq \alpha < 0.90$, moderate reliability for $0.50 \leq \alpha < 0.70$, and low reliability for $\alpha < 0.50$.(14) The level of statistical significance was set at 5%, and the SPSS (IBM Corp. Armonk, NY, version 21) statistical software package was used for the calculations.

RESULTS

Table 1 presented demographic data according to classes, including gender, average age, and treatment package. Table 2 showed the data of individuals with consistent and inconsistent anterior and total Bolton ratios across the classes. In the anterior Bolton ratio, 5, 10, and 7 individuals were found to have

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inconsistent recommended Bolton ratios in Class I, II, and III, respectively. For the total Bolton ratio, 6, 5, and 5 individuals in Class I, II, and III, respectively, were identified with inconsistent recommended Bolton ratios.

Table 1. Distribution of demographic characteristics by classes and packages.

		Class I	Class II	Class III	Total
Gender	**Female**	32	30	19	120
	Male	11	19	9	
Age (M ± SD)		28.4 ± 8.63	27.14 ± 9.18	27.36 ± 7.88	27.64 ± 8.64
Package	**Lite**	6	3	2	120
	Moderate	4	1	1	
	Comprehensive	33	45	25	

Table 3 displays the statistical comparisons of the anterior Bolton ratio, total Bolton ratio, recommended anterior Bolton ratio, and recommended total Bolton ratios among the classes. It was found that only the mean of the recommended anterior Bolton ratio in individuals with Class I malocclusion was significantly higher than in individuals with other malocclusions (p=0.008).

Table 2. Data of compliant and non-compliant individuals in the overall bolton ratio and anterior bolton ratio within classes.

	Class	Compliant (n)	Non compliant (n)
Anterior Bolton Ratio	**I**	38	5
	II	39	10
	III	21	7
Overall Bolton Ratio	**I**	37	6
	II	44	5
	III	23	5

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Table 3. Comparisons of anterior bolton ratio, overall bolton ratio, recommended anterior bolton ratio and recommended overall bolton ratio between classes.

	Class	n	Mean	SD	Min	Max	*p*
Anterior Bolton Ratio	I	43	.1307	.37990	.00	1.89	.728
	II	49	.1963	.61617	.00	3.75	
	III	28	.1107	.46222	.00	2.42	
Overall Bolton Ratio	I	43	.4612	.89087	.00	3.38	.448
	II	48	.2627	.55102	.00	2.38	
	III	28	.4221	.92357	.00	3,49	
Recommended Anterior Bolton Ratio	I	43	.1814[a]	.49917	.00	2,50	**.008**
	II	49	.0000[b]	.00000	.00	.00	
	III	28	.0000[b]	.00000	.00	.00	
Recommended Overall Bolton Ratio	I	43	.1558	.44040	.00	2.10	.245
	II	49	.2306	.64395	.00	3.00	
	III	28	.0321	.17008	.00	.90	

ANOVA test, SD : Standart Deviation, Min: Minimum, Max: Maximum, n: number of individuals, a-b: No difference between classes with the same letter, $p<0.05$

Table 4 presents the comparison of Cronbach's alpha between the anterior Bolton ratio and recommended anterior Bolton ratio and between the total Bolton ratio and recommended total Bolton ratio for all individuals. Cronbach's alpha for the anterior Bolton ratio and recommended anterior Bolton ratio was 0.131, and for the total Bolton ratio and recommended total Bolton ratio, it was 0.41. Both values indicate low reliability.

Table 4. Comparison of the Cronbach's Alpha value of the mean of the anterior bolton ratio and the mean of the recommended anterior bolton ratio, and the Cronbach's Alpha value of the mean of the overall bolton ratio and the recommended overall bolton ratio in all individuals.

	n	Mean	SD	Min	Max	α
Anterior Bolton Ratio	120	.1528	.50391	.00	3.75	0.131
Recommended Anterior Bolton Ratio	120	.0650	.30915	.00	2.50	
Overall Bolton Ratio	120	.3719	.77907	.00	3.49	0.41
Recommended Overall Bolton Ratio	120	.1575	.49818	.00	3.00	

Cronbach's Alpha Reliability, SD : Standart Deviation, Min: Minimum, Max: Maximum, n: number of individuals

DISCUSSION

Digital models can accurately obtain linear distances (15,16). Clear aligner software also provides data for some ratios derived from linear measurements, such as the Bolton analysis (8,9). However, there seems to be a gap in the literature regarding the interpretation of these data in treatment options such as leaving a diastema after treatment or IPR during treatment. Studies comparing real mesiodistal measurements of teeth with software-generated Bolton analyses exist (8,9). Current study, however, was conducted to determine the reliability of IPR planning corresponding to Bolton ratios the software identified. In our study, inconsistencies in the recommended IPR amount were found in 22 individuals for the anterior Bolton ratio and in 16 individuals for the total ratio. Furthermore, Cronbach's alpha for the anterior Bolton ratio and recommended anterior Bolton ratio as well as the total Bolton ratio and recommended total ratio were determined to be of low reliability. Therefore, our study's null hypothesis, H0, was accepted.

What is ClinCheck's working principle? This is not fully known (17). It is stated that the software used in clear aligner treatments provides outputs based on specific algorithms and inputs (18). Invisalign's website also mentions that it is a cloud-based software supported by data from over 16 million smiles (19). The fact that the software decides where to place optimized attachments without clinician intervention and the limited information about the software suggests it may offer similar treatments to those used in previous malocclusion cases. This seems akin to the system in which numerous images of certain diseases are input into an artificial intelligence database, which then provides preliminary diagnoses when it recognizes similar patterns (20). Nevertheless, many factors affect an individual's orthodontic treatment, including malocclusion type, crowding degree, age, gender, and cooperation (21). Therefore, each orthodontic problem requires a patient-specific orthodontic treatment plan. Even though Invisalign claims to provide treatment plans within minutes without technician involvement, the clinician's role remains crucial for accurate and realistic treatment planning despite all the technological infrastructure.

The recent literature on orthodontics confirms the clinical applicability and validity of the accuracy and reliability of linear measurements, such as space analysis and mesiodistal lengths of teeth, calculated using three-dimensional scanners and software (22–29). However, the treatment plans these software programs offer

do not seem as consistent as linear measurements. Different software can suggest different treatment plans for the same malocclusion (18). Based on Bolton analysis results, a clinician can choose to leave space after treatment or apply IPR during treatment (30). In this context, Andrews' six keys to occlusion, including factors such as molar relationship, crown angulation, crown inclination, absence of rotations, absence of spaces, and the Spee curve, are essential for a correct occlusal relationship (31). Here, even if there is no mesiodistal discrepancy in maxillary and mandibular teeth, the position and inclinations of the incisors are important for proper alignment.

Variability in 1-NA and 1-NB angles and positions can lead to excess space or crowding on the arch. Therefore, in addition to photos and scan images, it is suggested that individuals' cephalometric values should also be reported in the treatment planning software. Additionally, the software should define limits for incisor position and angle. A recent application mentioned the possibility of importing CBCT images into the program (3). However, the lack of indication for every patient and still not providing cephalometric values highlights the importance of clinician vigilance regarding the software.

What is the threshold value of the Bolton discrepancy? Proffit (32) suggested that significant anterior Bolton ratio discrepancies are likely when the upper lateral incisor is not larger than the lower lateral incisor. Additionally, he reported that for posterior Bolton ratio consistency, the second upper and lower premolars should be equal. He also mentioned that Bolton discrepancies under 1.5 mm are not clinically significant. Many studies have typically defined a Bolton discrepancy as 1.5 mm (33–37). Othman and Harradine (13), however, suggested a threshold value of 2 mm for this discrepancy. In the current study, a 2-mm threshold value was accepted, thus considering discrepancies exceeding 2 mm between the Bolton discrepancy identified by ClinCheck software and its recommended IPR amounts as inconsistent.

Martin et al. (8) indicated that although ClinCheck Pro 6.0's results show a positive bias, its measurements for tooth widths, excluding molars, are acceptable. However, they also noted that the software does not use the original Bolton formula and especially in cases of mandibular excess, the anterior Bolton ratio and total Bolton ratio values are not accurate and clinically unacceptable. Shailendran et al. (9) reported that although optical profilometer and caliper measurements are reliable, ClinCheck Pro systematically

underestimates the mesiodistal widths of teeth, with this systematic error increasing toward the posterior of the arch. They found the software moderately reliable for Bolton values.

Zhang et al. (38) evaluated the incidence of open gingival embrasure formations following clear aligner treatment in a large sample. In their study of 2500 individuals, they reported encountering open gingival embrasures in 25.7% of cases between maxillary incisors and 40.3% between mandibular incisors posttreatment. They also emphasized that the IPR process did not prevent this problem. This high incidence rate is concerning. Although their study seems different in subject from ours, it suggests that ClinCheck does not account for the inclination and position of incisors. This supports the need for clinical evaluation of linear and proportional deviations in treatment plans, reinforcing the results of our study. Hariharan et al.(39) stated that the amounts of IPR ClinCheck determines often surpass the actual need. Additionally, our study was conducted to compare the values the software program detected and suggested, revealing weak reliability between the identified anterior Bolton ratio and the suggested anterior Bolton ratio and between the total Bolton ratio and the suggested total Bolton ratio.

The lack of knowledge about how the software calculates the Bolton ratio and the exclusion of software besides ClinCheck from the study are limitations. Further research is needed with a larger sample size and modifications in the software to incorporate incisor position and inclination values.

CONCLUSION

A weak reliability relationship was identified between Bolton values obtained with ClinCheck software and the IPR proposals in the treatment planning. This finding highlights the potential benefits of developing versions of the software that can integrate cephalometric values, such as incisor positions and inclinations.

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Authorship contributions

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Data availibity statement

Not applicable.

Declaration of competing interest

The authors have stated explicitly that there are no conficts of interest in connection with this article.

Ethics

This study commenced with the approval of the Non-Invasive Clinical Research Ethics Committee of Van Yüzüncü Yıl University (2023/13-11).

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