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CLINICAL RESEARCH

Effect of prerestorative short-term clear aligner therapy in restorative treatment planning

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ABSTRACT

Statement of problem. One of the major challenges in restorative dentistry is to provide optimal esthetics in a minimally invasive way. The optimization of dental esthetics and function is directly related to the position and alignment of the anterior teeth, but whether prerestorative clear aligner therapy will enhance esthetics and minimize restorative needs is unclear.

Purpose. The purpose of this clinical study was to evaluate the effect of prerestorative maxillary and mandibular second premolar to second premolar clear aligner therapy in minimizing the need for restorative treatment.

Material and methods. Fifty adult patients treated with clear aligners (Invisalign Go; Align Technology) were included in this study. Previously generated 3-dimensional orthodontic simulations and clinical photographs in the ClinCheck/6.0 software program were used. Three restorative treatment plans for each participant were generated for initial (no aligners), Express (after using 7 aligners), and Lite Packages (after using 20 aligners) by 2 blinded restorative dentistry instructors. The maxillary and mandibular teeth in the smile-line (to the second premolars) were included. Assessment criteria were the estimated number of restorations, restoration surfaces and preparations and incisal edge inclusion, and the need for gingival leveling. The Friedman test and Cochran Q test were used for statistical analyses (α=.05).

Results. A strong positive correlation was found between the 2 instructors (P<.001). Estimated number of restorations (10 [3 to 16][a]) decreased significantly for Express (6 [0 to 14][b]) and Lite Packages (4 [0 to 8][c]) (P<.001). The estimated number of restoration surfaces (28.5 [9 to 48][a]) decreased significantly for Express (15 [0 to 42][b]) and Lite Packages (9.5 [0 to 24][c]) (P<.001). While the estimated number of teeth to be prepared for recontouring (7 [0 to 16][a]) was significantly less for Express (3 [0 to 10][b]) and Lite Packages (0 [0 to 4][c]) (P<.001), the incisal edge inclusion (10 [3 to 16][a]) was significantly less for Express (6 [0 to 14][b]) and Lite Packages (4 [0 to 8][c]) (P<.001). The need for gingival leveling (26 [52%][a]) decreased significantly for Express (20 [40%][a]) and Lite Packages (7 [14%][b]) (P<.001).

Conclusions. Prerestorative short-term clear aligner therapy might conserve tooth structure and reduce the number of restorations. The application of the Invisalign Lite Package was more effective than the Invisalign Express Package for second premolar to second premolar alignment. (J Prosthet Dent 2023;■:■-■)

The best possible esthetic outcome with the most conservative restorative option is essential when treatment planning.[1-4] The excellent long-term function of a restoration with only moderate esthetics might be a better choice compared with optimal esthetics with compromised function.[5,6] Compromised function includes the risk of restoration fracture during dynamic jaw movements, recurrent caries, and need for endodontic therapy.[2,3,7,8] Magne et al,[9] in 2002, presented a modified checklist including 14 criteria to guide the clinician to esthetic restorative success (Fig. 1). The 14 objective clinical principles for the anterior teeth and surrounding soft tissues are necessary for generating the common elements of a beautiful smile and for defining its normality.[9]

Prerestorative alignment of the teeth with orthodontic appliances has commonly

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Clinical Implications

Prerestorative short-term second premolar to second premolar clear aligner therapy should be effective in reducing the number of procedures in the restorative treatment plan.

been used to reduce tooth preparation.[4,10] However, patients generally tend to reject this advantageous option because of the time needed for the orthodontic treatment and especially the unesthetic appearance of conventional orthodontic appliances.[11] These concerns were addressed with a clear aligner system (Invisalign; Align Technology), first introduced in 1999.[12-14] Through conventional dental impressions or digital scanning, this system provides precise 3-dimensional individual casts and a related virtual individual diagnostic posttreatment tooth arrangement in a software program (ClinCheck; Align Technology).

The software program allows the assessment of individual tooth movements for each aligner stage.[14] The clinician can request modifications to the proposed treatment plan until the required result is achieved.[15-17] The gingival contour, cervical level, and symmetry are also simulated virtually in the software program (Fig. 2). Following agreement on the definitive plan, a computer-aided manufacturing process fabricates a series of clear polycarbonate aligners.[14] The patient wears each of the aligners for at least 22 hours a day for 7 to 10 days until the final aligner.[10] The workflow for prerestorative clear aligner therapy (CAT) is presented in Figure 3.

Weinstein et al[5] first introduced the prerestorative short-term CAT concept in the smile-line in 2021 as a predictable option for achieving minimally invasive restorative goals.[5,12] They suggested a partial official version of the system (Invisalign Go; Align Technology), which was limited to the anterior teeth between the second premolars. CAT was considered to be better perceived by the adult population than conventional orthodontic treatment with brackets because of improved appearance.[5,18-20] The limits of prerestorative short-term CAT were considered up to 20 aligners (Table 1).[6] The suggested limits allow restorative goals to be achieved in a minimally invasive or even noninvasive way.[12]

This research aimed to assess the effect of prerestorative short-term CAT in restorative treatment planning for anterior esthetics in terms of minimally invasive dentistry. The null hypotheses were that CAT would have no effect on the predicted number of teeth to be restored, the predicted number of restoration surfaces, the predicted number of incisal edges involved, the predicted number of teeth to be prepared, and the need for gingival leveling.

MATERIAL AND METHODS

This study was approved by a local ethical committee (approval no: 2022/100 and date: 27.10.2022). Fifty adult patients who had been treated with the Invisalign system were assessed in this study. Initial and follow-up records of the patients obtained from intraoral scanning and dental photography were used for the evaluations. The previously generated 3-dimensional orthodontic treatment simulations for individual tooth movements and related dental photography records in the software program (ClinCheck/6.0; Align Tech) were used. Through the software program, restorative treatment plans were provided for the anterior teeth in the smile-line (maxillary and mandibular incisors, canines, and premolars) by 2 blinded restorative dentistry instructors (B.K., T.U.). The plans were performed at the initial stage and after using clear aligners at the other 2 stages. One was performed after 7 aligners and the other after 20 aligners (corresponding to the Express Package and Lite Package in the Invisalign system, respectively). As a result, each instructor performed 3 different restorative treatment plans for each patient. Limited to the teeth in the smile-line, the assessment criteria for generating the restorative treatment plans were the estimated number of restorations, the estimated number of restoration surfaces, the estimated number of teeth to be prepared for recontouring, the inclusion of the incisal edge, and the need for gingival leveling.

The participants included in the study were selected from completed treatments in the Invisalign Global Gallery (treated pool), were without systemic diseases, and were aged between 18 and 55 years. They had a limited need for orthodontic tooth movement and had previously used a maximum of 20 clear aligners with the Invisalign system as a prerestorative treatment. All the selected patients who initially needed at least 1 esthetic restoration for the teeth in the smile-line (including maxillary and mandibular incisors, canines, and premolars) were included. The reasons for the restoration included carious lesions, erosive lesions, uncomplicated crown fractures, diastemas, vertical axis, torque and position misalignments, congenital malformations, and intrinsic discolorations. Those with midline discrepancy, open occlusal relationship or vertical overlap, and edge-to-edge anterior interocclusal relations at the initial stage were also included. Those who had more than 20 aligners for the Invisalign treatment, those having interproximal reductions (IPR) in orthodontic treatment simulations, those with previous indirect restorations on the teeth (crowns, inlays, onlays, or ceramic veneers) in the smile-line (including maxillary and mandibular incisors, canines, and premolars), those with severe periodontal disease, and those with posterior disocclusion were excluded from the study.

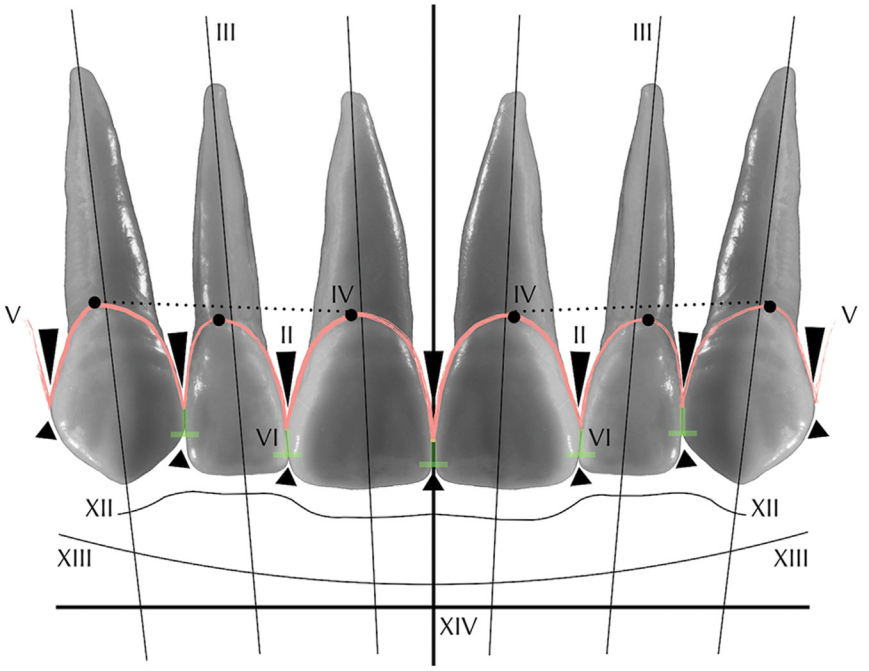

Figure 1. Checklist for esthetic restorative success. I, Gingival health; II, interdental closure; III, tooth vertical axis; IV, gingival trigone; V, gingival level; VI, level of interdental contact; VII, relative tooth dimensions; VIII, tooth form; IX, tooth characterization; X, surface texture; XI, color; XII, incisal edge level; XIII, lower lip line; XIV, smile symmetry.

Figure 2. A, Initial intraoral photograph. B, Virtual diagnostic pretreatment design. C, Virtual diagnostic posttreatment design. D, Final intraoral photograph.

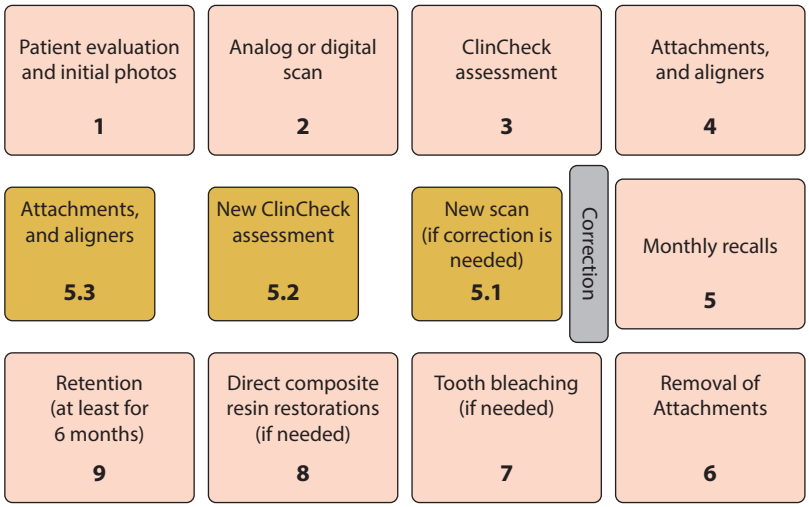

Figure 3. Clinical workflow for prerestorative clear aligner therapy guided direct anterior restorations.

Table 1. Limits of prerestorative clear aligner therapy application

Misalignment	Limit
Crowding or spacing	≤7 mm
Arch-width expansion	4 mm per arch
Vertical overlap or open occlusal relationship	≤5 mm total
Midline discrepancy	1 mm
Rotated tooth	Up to 20°
Number of aligners per arch	Up to 20 aligners
Additional aligners	One more set (2 sets total)

Table 2. Correlation between 2 observers regarding evaluation criteria

Treatment Stage	ICC (%95 CI)	P*
No aligners (0)	0.934 (0.914-0.950)	**<.001**
Express Package (7)	0.937 (0.918-0.952)	**<.001**
Lite Package (20)	0.865 (0.825-0.896)	**<.001**

*Cochran Q test, n (%).

The data were analyzed with a statistical software program (IBM SPSS Statistics, v23; IBM Corp). A pilot study was performed to evaluate the effect size of each evaluation criterion and was found as 0.664, 0.703, 0.664, 0.666, and 0.312 respectively. The power of the study was found to be 97.5% according to a post hoc power analysis. The normality of the data was evaluated by using the Kolmogorov-Smirnov test. Alpha values were .14 for criterion 1 with Lite Package, .021 for criterion 2 with Lite Package, <.001 and .014 for criterion 3 with Lite and Express Packages respectively, <.001 for criterion 4 with Lite Package, and <.001 for criterion 5 with all. Because the data were not normally distributed, the Friedman and Dunn tests were used. The Friedman test was used to assess the changes in the evaluation criteria over time. The categorical assessment of the evaluation criteria was performed with the Cochran Q test. The correlation between the 2 examiners was checked with the intraclass correlation coefficient (ICC). The results were presented as average ±standard deviation for the quantitative data and median (min to max) for the categorical data (α=.05).

RESULTS

Regarding the ICC results, a positive and very strong correlation was found between the 2 blinded observers regarding the assessments for the evaluation criteria at each treatment stage (P<.001 for each stage) (Table 2). Regarding the Friedman and Dunn test results, all the evaluated criteria presented significant differences regarding the number of aligners used (Table 3). The estimated number of restorations decreased significantly for the Express Package (6 [0 to 14]) compared with no aligner use (10 [3 to 16]) (P<.001), and a significant decrease was also observed for the Lite Package (4 [0 to 8]) compared with the Express Package (P<.001). The estimated number of restoration surfaces decreased significantly for the Express Package (15 [0 to 42]) compared with no aligner use (28.5 [9 to 48]) (P<.001), and a significant decrease was also observed for the Lite Package (9.5 [0 to 24]) compared with the Express Package (P<.001). The estimated number of teeth to be prepared for recontouring decreased significantly for the Express package (3 [0 to 10]) compared with no aligner use (7 [0 to 16]) (P<.001), and a significant decrease was also observed for the Lite package (0 [0 to 4]) compared with the Express Package (P<.001). The estimated number of restorations including the incisal edge decreased significantly for the Express Package (6 [0 to 14]) compared with no aligner use (10 [3 to 16]) (P<.001), and a significant decrease was also observed for the Lite Package (4 [0 to 8]) compared with the Express Package (P<.001).

Regarding the Cochran Q test results, no significant difference was observed between no aligner use and the

Table 3. Assessment of evaluation criteria regarding number of aligners

Criteria	Number of Aligners	Average(±St Dev)	Median (Min-Max)	Test Statistics	P*
Estimated number of restorations	No aligners (0)	10 ±3.37	10 (3-16)[a]	90.514	**<.001**
	Express Package (7)	6.02 ±3.05	6 (0-14)[b]		
	Lite Package (20)	3.66 ±2.2	4 (0-8)[c]		
Estimated number of restoration surfaces	No (0) aligners	28.74 ±10.67	28.5 (9-48)[a]	90.626	**<.001**
	Express Package (7)	16 ±9.4	15 (0-42)[b]		
	Lite Package (20)	9.22 ±6.09	9.5 (0-24)[c]		
Estimated number of prepared t eeth for recontouring	No aligners (0)	7.72 ±4.28	7 (0-16)[a]	86.561	**<.001**
	Express Package (7)	3.2 ±2.95	3 (0-10)[b]		
	Lite Package (20)	0.7 ±1.09	0 (0-4)[c]		
Estimated number of restorations i ncluding incisal edge	No aligners (0)	9.92 ±3.42	10 (3-16)[a]	90.213	**<.001**
	Express Package (7)	5.84 ±3.1	6 (0-14)[b]		
	Lite Package (20)	3.54 ±2.22	4 (0-8)[c]		

Rows with same letter statistically similar. Bold values indicate Statistically significant. *Friedman test.

Express Package regarding the need for gingival leveling ($P \geq .05$) (Table 4). However, a significant decrease was found for the Lite Package (7 [14]) compared with the Express Package (20 [40]) and no aligner use (26 [52]) ($P < .001$).

Table 4. Assessment for need for gingival leveling regarding number of aligners

	Need for Gingival Leveling			
Number of Aligners	Not Needed	Needed	Test Statistics	P*
No aligners (0)	24 (48)	26 (52)[a]	29.789	**<.001**
Express Package (7)	30 (60)	20 (40)[a]		
Lite Package (20)	43 (86)	7 (14)[b]		

Rows with same letter statistically similar. Bold value indicates Statistically significant. *Cochran Q test, n (%).

DISCUSSION

The null hypotheses were rejected, as significantly more minimally invasive restorative treatment plans were performed after the short-term CAT. Though previous findings regarding the limited control of simple movements with clear aligners such as tipping or slight rotation, the aimed correction limits for the prerestorative CAT relatively met expectations.[15] Karras et al[16] specified that composite resin attachments can be effective for these complex movements. They also suggested overcorrection for anterior tooth extrusion from 0.4 mm to 0.6 mm and rotation from 4 to 6 degrees. The accuracy and efficacy of tooth movements with clear aligners have improved since 2009 from an overall mean accuracy of 41% to 50% according to reports in 2020.[17,21] Additionally, the percentage accuracy might be higher for the CAT because of the limited tooth movements and avoidance of major tooth movements which are more prone to relapse.[21] Moreover, the shorter treatment duration compared with the fixed orthodontic appliances provide additional patient motivation.[15,17] The CAT has minimal effect on dental plaque accumulation, which reduces the risk of dental caries,[22,23] white-spot lesions, and gingival inflammation.[12] Therefore, CAT can be recommended for less compliant patients with periodontal problems.[11]

Systematic reviews of the effectiveness and predictability of the mid-term and long-term orthodontic aligners have concluded that the treatment outcome was patient-dependent and that inclination and rotation were the most challenging tooth movements.[18-20] However, the authors are unaware of studies that evaluated the clinical effects of short-term clear aligner therapy on future restorative treatment. Therefore, through computer-aided 3-dimensional simulations, this study assessed the clinical effectiveness of short-term CAT on anterior restorative treatment plans. The positive and very strong correlation between the 2 blind observers indicated the standardized generated treatment plans (Table 2). As a result, the observer's subjectivity was not considered a limitation for the assessments.

The ability of the clinician to optimize dental esthetics and function is directly related to the position and alignment of the teeth.[13,14] Moreover, an esthetic smile is a subjective perception, depending on the balanced integration of white and pink esthetics within an individual smile.[1-3] A checklist of esthetic restorative success should guide the clinician, and a conservative treatment path should be determined before restoration (Fig. 1). Several esthetic parameters in the checklist can be improved with prerestorative approaches such as resin infiltration, microabrasion, whitening, and through multidisciplinary periodontal treatment and orthodontic alignment.[12] Orthodontic alignment is one of the best prerestorative solutions for correcting the vertical axis, torque, and/or position of the teeth.[10,13] Gingival trigone points, tooth vertical axis, gingival level, level of interdental contact, incisal edge level, and smile symmetry can be corrected before the restorative procedure through short-term CAT, and, eventually, the smile esthetics can be improved with minimal restorative interventions.[5] In

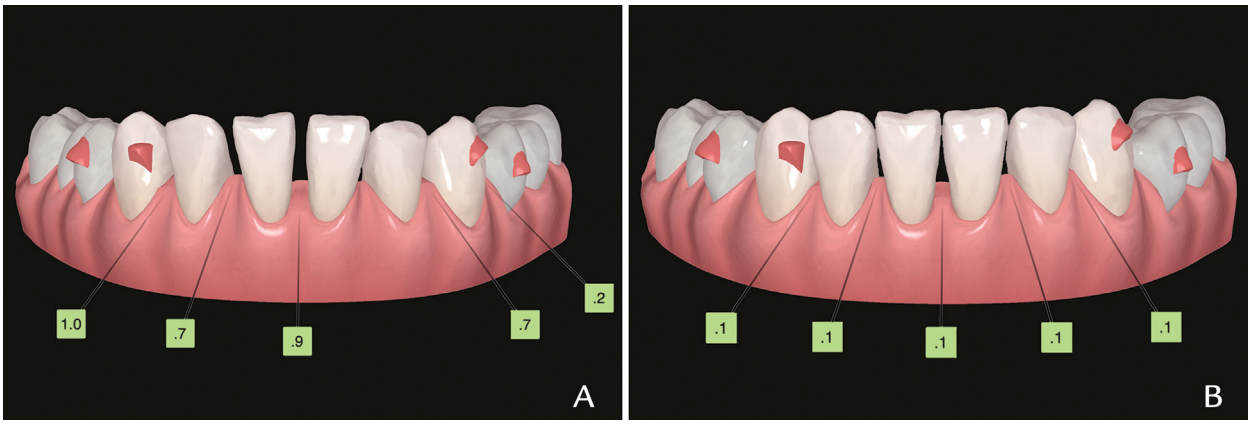

Figure 4. A, Virtual diagnostic pretreatment design. B, Virtual diagnostic posttreatment design and rearrangement of mandibular diastemas with Express Package.

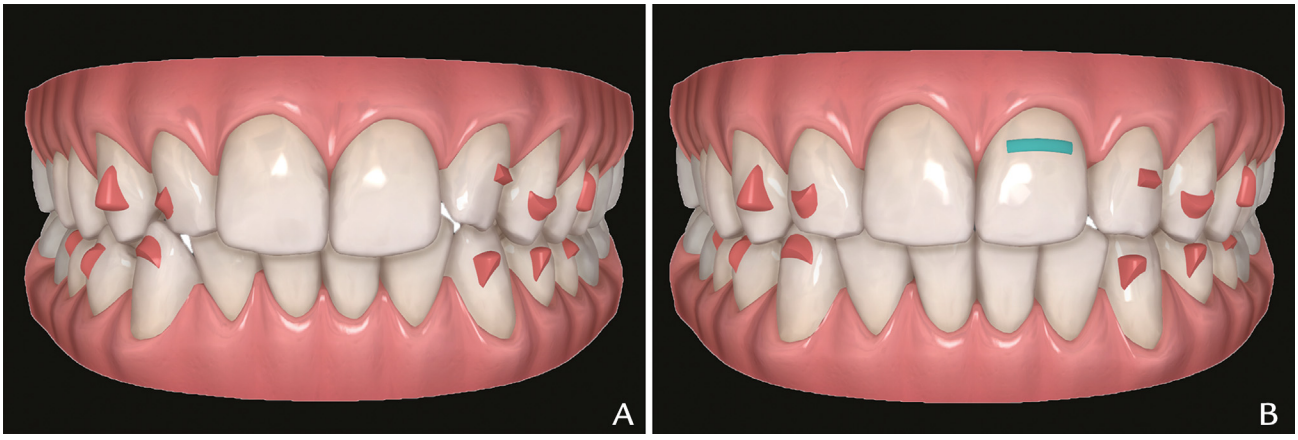

Figure 5. A, Virtual diagnostic pretreatment design. B, Virtual diagnostic posttreatment design and correction of rotation and angulation of maxillary lateral incisors with Lite Package.

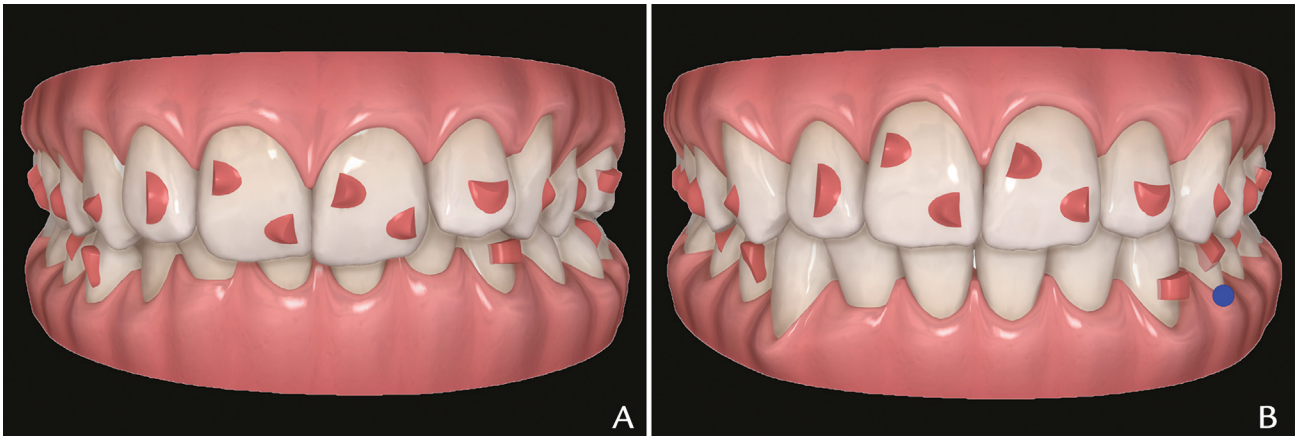

Figure 6. A, Virtual diagnostic pretreatment design. B, Virtual diagnostic posttreatment design and correction of vertical axis, torque of maxillary incisors, and vertical overlap with Lite Package.

the present study, virtual 3-dimensional orthodontic tooth movements were performed on 2 different levels to prepare the patient for a more conservative restoration plan.

The number of anterior restorations can be an influencing factor for a patient's standard of living and has been mainly associated with esthetic and functional problems.[1-3] Additionally, direct anterior restorations

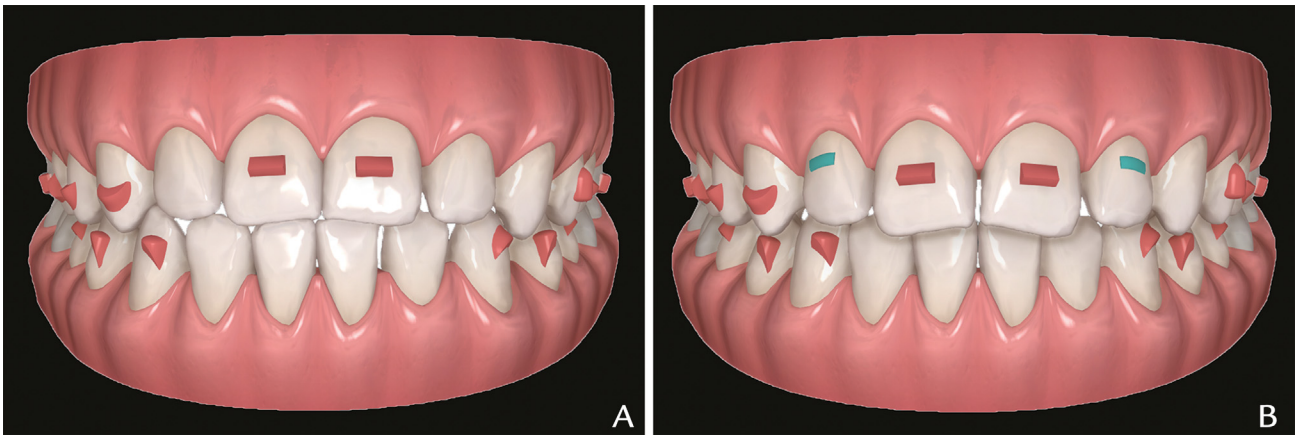

Figure 7. A, Virtual diagnostic pretreatment design. B, Virtual diagnostic posttreatment design and correction of edge-to-edge anterior occlusal relations by providing maxillary diastemas with Lite Package.

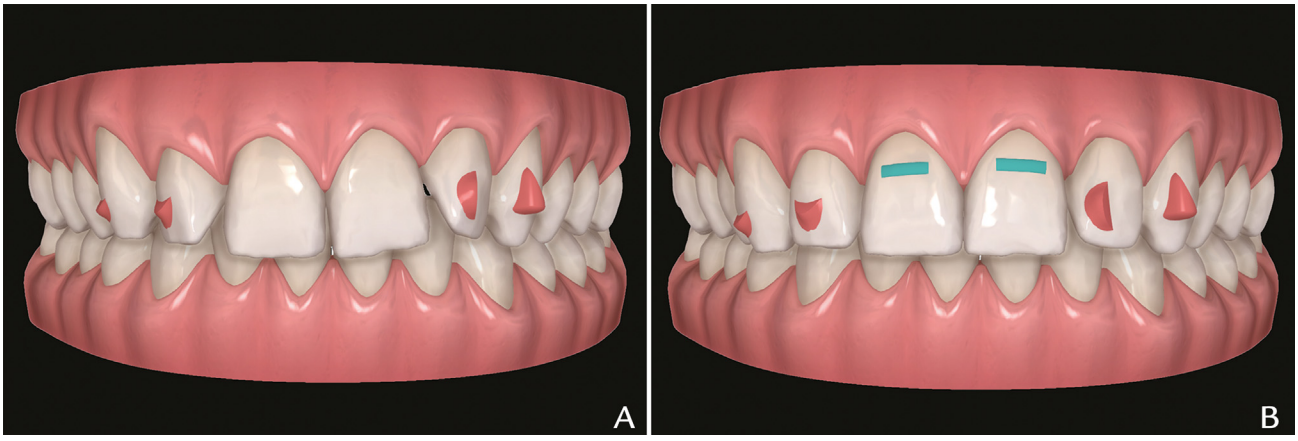

Figure 8. A, Virtual diagnostic pretreatment design. B, Virtual diagnostic posttreatment design and effect of CAT on gingival cervical levels using Express Package. CAT, clear aligner therapy.

have been reported to be more prone to marginal discoloration and staining than indirect restorations.[2] In addition, marginal chipping and restoration fracture can lead to esthetic and functional problems. In the present study, the positions of the incisors, canines, and premolars were reorganized prerestoratively while evenly distributing the existing spaces to help create direct anterior restorations in optimal proportions with minimal preparation (Fig. 4). The midline was repositioned when needed considering that up to 3 mm to 4 mm of midline deviation has been reported to be unnoticeable.[6,24] The repositioning was performed to equalize the symmetrical tooth proportions, which is an important factor in smile esthetics.[4] Moreover, the rotations and inclinations of incisors by 2 mm to the right or left were considered unesthetic.[4,6,24] Therefore, the torque, vertical axis, and rotation of the teeth were totally or partially corrected within the limits of the short-term CAT. This correction was performed to eliminate or minimize the potential preparations for recontouring before the restorative treatment (Figs. 5, 6). According to the results, fewer anterior restorations including fewer restoration surfaces could be performed following the prerestorative CAT. The number of restorations and restoration surfaces were inversely proportional to the number of aligners used (Table 3). Therefore, the first 2 null hypotheses of the study were rejected.

Restorations including more than 1 tooth surface and especially those including the incisal edge have been reported to be more prone to fracture, when subjected to high masticatory loads because of the weak mechanical retention of resin-based materials.[1,2,12] Heintze et al[3] reported Class IV restorations as having twice the fracture rate of Class III restorations, and Van Dijken et al[25] indicated bruxism as a major factor in increasing the failure rate. The prerestorative repositioning of the teeth

in this study will have led to a significant decrease in the number of incisal edge restorations, which was inversely proportional to the number of aligners used (Table 3). Thus, the third null hypothesis of the study was rejected.

The short-term prerestorative CAT might also transform the existing occlusal pattern into a more protective pattern such as canine-guided occlusion (CGO) or group function occlusion (GFO) before the restorative procedure.[12] The occlusion pattern together with parafunctional habits and the properties of the selected restorative material influence the longevity of the restoration.[3,7,12] Therefore, the prerestorative correction of problematic occlusal relations may improve the lifetime of anterior restorations. For some patients in the present study, diastemas were created between the maxillary anterior teeth to overcome the edge-to-edge anterior occlusal relationship (Fig. 7).

The estimated number of the teeth to be prepared for recontouring was inversely proportional with the number of aligners used, and no preparation was needed for some patients after using 20 aligners (Table 3). Therefore, the fourth null hypothesis was rejected. The prerestorative correction of malpositioned teeth and the even distribution of the existing spaces probably explain this result.

Gingival tissue was visible for 43.6% of the patients.[8] Gingival contours should be considered during the restorative treatment planning of the smile-line. The maxillary incisors and canines have been described as the principal teeth determining the gingival contour of a smile.[26] Ideal gingival contour can be determined by evaluating the width-to-length ratio of the maxillary anterior teeth and by determining the desired amount of gingival display.[4] From a restorative perspective, it is better to increase the crown length by adjusting the gingival cervical line than by extending the incisal edge, risking fracture.[1,2,4] The adjustment of the cervical line can be performed by either periodontal treatment or orthodontic tooth movement.[4,12] In the present study, the use of 7 aligners did not significantly affect the need for gingival leveling ($P \geq .05$), whereas the need for gingival leveling significantly decreased for 20 aligners ($P < .001$) (Table 4) (Fig. 8). Thus, the fifth null hypothesis of the study was rejected. As a result, the prerestorative short-term CAT can be considered a minimally invasive procedure for improving gingival levels.

Limitations of the study included that the tooth movements of rotation, intrusion, and extrusion with CAT have been considered to be relatively restricted.[20,27] Moreover, the effectiveness of clear aligner treatment is affected by the quality of the aligner material, clinician-dental laboratory technician communication, clinician expertise, and the cooperation of the patient,[12,19] considerations that also apply to the prerestorative CAT procedure. However, the ability to modify the final outcome with direct or indirect restorative approaches is an important advantage that can eliminate these limitations. The effectiveness of clear aligner systems other than the Invisalign system should be determined in further studies.

CONCLUSIONS

Based on the findings of this clinical study, the following conclusions were drawn:

1. The prerestorative short-term second premolar to second premolar CAT with the Invisalign system was effective in minimizing the invasiveness of the restorative treatment plan.
2. The estimated number of restorations, the number of restoration surfaces, the number of involved incisal edges, and the number of teeth to be prepared for recontouring should decrease following the CAT, and the gingival levels should be adjusted before the restorative procedures.
3. The Lite Package (20 aligners) was more effective than the Express Package (7 aligners).
4. Short-term CAT is an appropriate option in dental treatment planning for minimally invasive dentistry.

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