Original Article

Improvement in smile esthetics following orthodontic treatment
A retrospective study utilizing standardized smile analysis

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ABSTRACT

Objective: To quantify smile esthetics following orthodontic treatment and determine whether these changes are correlated to the severity of the initial malocclusion.

Materials and Methods: A standardized smile mesh analysis that evaluated nine lip-tooth characteristics was applied to two groups of successfully treated patients: group 1 (initial American Board of Orthodontics Discrepancy Index [DI] score <20) and group 2 (initial DI score >20). *T*-tests were used to detect significant differences between the low-DI and high-DI groups for baseline pretreatment measurements, baseline posttreatment measurements, and changes from pre- to posttreatment. A Spearman correlation test compared the initial DI values with the changes in the nine smile measurements.

Results: Five of the smile measurements were improved in both groups following orthodontic treatment. Both groups demonstrated improved incisor exposure, an improved gingival smile line, an increase in smile width, a decreased buccal corridor space, and an improvement in smile consonance. Spearman correlation tests showed that initial DI value was not correlated to changes in any of the individual smile measurements.

Conclusions: Smile esthetics is improved by orthodontic treatment regardless of the initial severity of the malocclusion. In other words, patients with more complex orthodontic issues and their counterparts with minor malocclusions benefitted equally from treatment in terms of their smile esthetics. (*Angle Orthod.* 2014;84:492–499.)

KEY WORDS: Smile esthetics; Smile mesh analysis; Standardized analysis; ABO Discrepancy Index

INTRODUCTION

Orthodontists must develop an expert system of diagnosis to set their treatment goals for each patient. The basis for this system has been heavily debated and led to multiple methods of cephalometric and soft tissue measurement. Since the development of roentgenographic cephalometry in 1931, the majority of objective analyses examined patients from the lateral perspective, establishing a vast database of normal values.[1–3] Patients, however, generally view themselves from the front and judge treatment success in terms of their smile improvement from the frontal perspective. Thus, several authors have asserted that an objective, standardized analysis of the frontal smile should be assigned greater importance in diagnosis and treatment planning.[4–6]

While all orthodontists aim to produce esthetic smiles, the lack of a standard objective analysis of the frontal smile has hindered research in this area. Many studies have examined the smile and its effects on perceived attractiveness, but a consistent technique for gathering smile data and analyzing them is not yet available. An important step in the development of an objective smile analysis involved defining smile reproducibility (Figures 1A,B). A posed smile is

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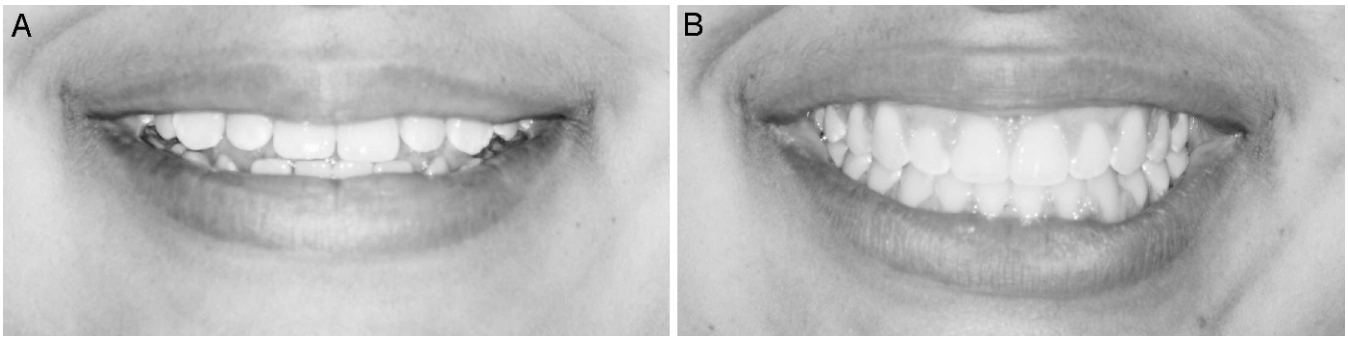

Figure 1. (A) A reproducible smile. (B) An unposed spontaneous smile.

voluntary, and it is far more reproducible than a spontaneous smile, which is elicited by emotion and is unsuitable for research purposes.[7,8]

When a person smiles with the lips parted, varying amounts of both upper and lower teeth are displayed. Depending on the elevation of the upper lip, maxillary gingiva may also show. The level of the upper lip during smiling is referred to as the *smile line*. If it lies above the maxillary incisors, it is called a *gingival smile line*. The smile line directly affects the amount of upper incisor display and can be recorded as millimeters of gingival display or as a percentage of incisor coverage (Figures 2A,B). The current literature suggests that an attractive smile shows 75% to 100% of the maxillary incisors and between 0 and 2 mm of gingiva.[9–14] Other authors have suggested that gingival levels above this should also be considered acceptable, since the smile line will lower as the patient ages.[15,16]

The interlabial gap, smile width, and smile index are interrelated esthetic measurements. The *interlabial gap* is the distance from the inferior border of the upper lip to the superior border of the lower lip during a posed smile (Figure 3A). The *smile width* is the distance between the outer commissures of the lips (Figure 3B). Because absolute measures of interlabial gap and smile width can vary depending on patient size, they are best described in proportions. Therefore, the *smile index* was created, which uses the interlabial gap measurement, divided by the smile width. It is generally accepted that a high smile index is more attractive.[13,15–17]

The *buccal corridor space* is the distance from the inner lip commissure to the most posterior visible maxillary tooth on each side (Figure 4). The current esthetic description for buccal corridor space is one that is full and symmetric yet with care taken not to completely eliminate the negative space, as this creates an artificial appearance.[12,14,18]

The *smile arc* is the curve that passes along the incisal edges of the maxillary anterior teeth. It is generally evaluated in comparison to the curvature of the lower lip during a posed smile. A smile arc is described as *consonant* if it follows the curvature of the lower lip and *nonconsonant* if it is not parallel to the lower lip (Figures 5A,B). The majority of research indicates that both orthodontists and laypeople find a consonant smile arc more attractive.[9,13,14,19]

A study that highlighted the need for a universal smile analysis demonstrated that an ideal posttreatment occlusion does not guarantee an attractive smile. Numerous studies found no correlation between any individual component or total combined score on the

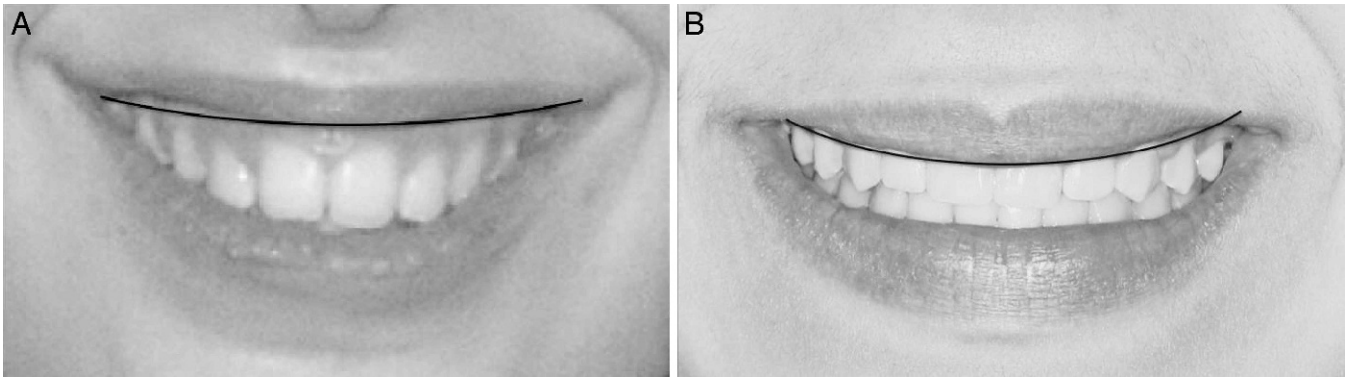

Figure 2. (A) Smile line demonstrating 100% of incisor and gingival display. (B) Smile line demonstrating 50% incisor display and no gingiva.

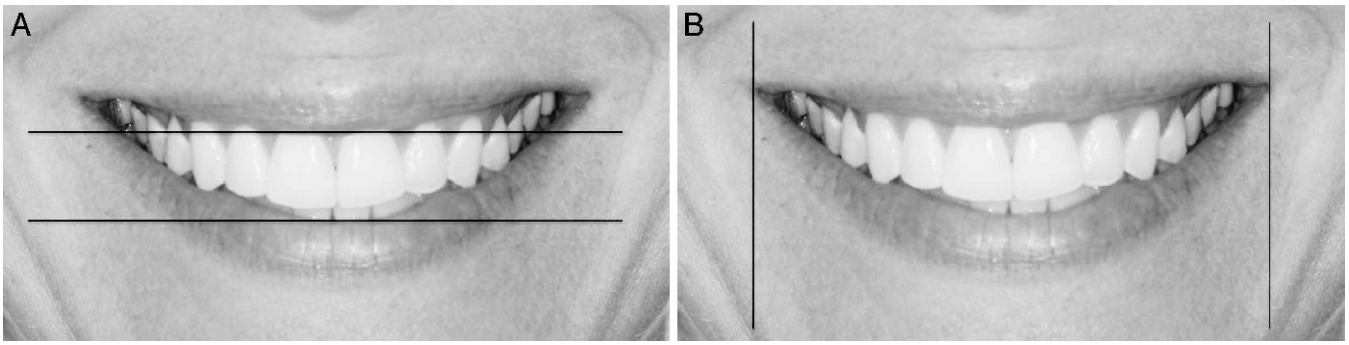

Figure 3. (A) Interlabial gap. (B) Smile width/index ratio.

Figure 4. Buccal corridor space.

American Board of Orthodontics' (ABO) Objective Grading System (OGS) and whether a smile is considered attractive or unattractive by a panel of raters. The authors called for the addition of smile analysis to the OGS to more adequately describe successful treatment outcomes.[20–26]

MATERIALS AND METHODS

A power analysis was conducted to determine the minimum sample size for a two-tailed test with $\alpha \leq .05$ with 80% power. Based on prior studies, it was assumed that measurements of incisor exposure and lip drape had to differ by 2 mm to be clinically significant and that only differences of greater than 3 mm in interlabial gap and smile width would be clinically notable.[4,17] It was determined that a minimum of 47 subjects would be necessary in each group.

Both male and female subjects who had successfully completed orthodontic treatment at the Montefiore Medical Center orthodontic clinics were included. Successful treatment was defined by an ABO OGS score $\leq$30 points at completion. After approval was obtained from the institutional research board (MMC #12-02-043), a database search was conducted; the first 47 subjects with an initial Discrepancy Index (DI) $<$20 points were classified as group 1 (mild malocclusion), whereas the first 47 subjects with a DI $>$20 points were classified as group 2 (severe malocclusion).

All photographs were obtained with a Canon Rebel T1i and a Sigma 105-mm macro lens with the focal distance standardized. After the subjects were grouped, their pre- and posttreatment smiling photos were cropped and a rectangular grid (''smile mesh'') was created. The upper margin of the rectangle was subnasale, the lower margin was 10 mm below the inferior border of the lower lip, and the lateral margins were 10 mm outside the right and left lip commissures. This resulted in 188 rectangles of varying sizes

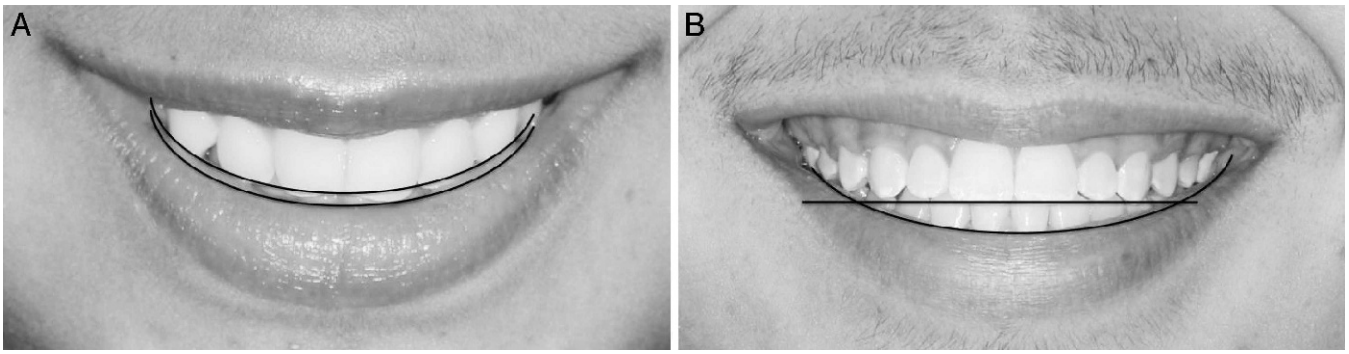

Figure 5. (A) Interlabial gap. (B) Smile width/index ratio.

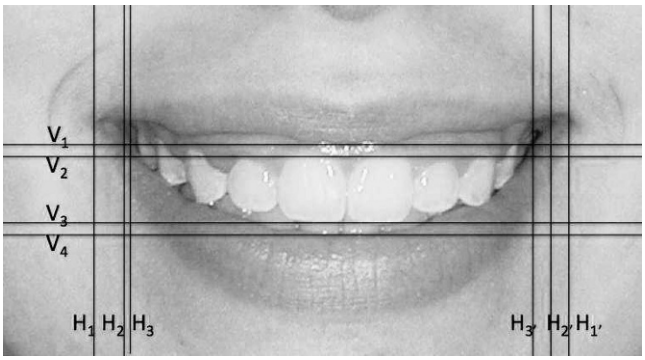

Figure 6. Smile mesh grid.

containing only the smile. To ensure calibration, the actual width of the upper right central incisor was measured from the digital model and proportionally applied to the cropped smile photograph. This process ensured that all smile mesh measurements would be comparable regardless of the original dimensions of the rectangular photograph.

Vertical and horizontal lines were then constructed on these calibrated smile photographs to form the smile mesh grid. The horizontal reference lines were placed at the inferior margin of the upper lip, at the central incisor gingival margin, at the incisal edge of the upper incisors, and at the superior margin of the lower lip. The vertical reference lines were placed at the outer left and right lip commissures, the inner left and right lip commissures, and the left and right uppermost posterior visible tooth (Figure 6).

With these grid lines constructed, eight smile characteristics were measured directly, whereas the ninth characteristic, smile arc, was determined by visual examination of the parallelism of upper anterior incisal edges to the lower lip line and recorded as consonant (yes) or nonconsonant (no).[4,17]

RESULTS

Statistical analyses focused on three main questions: (1) Were there within-group changes from

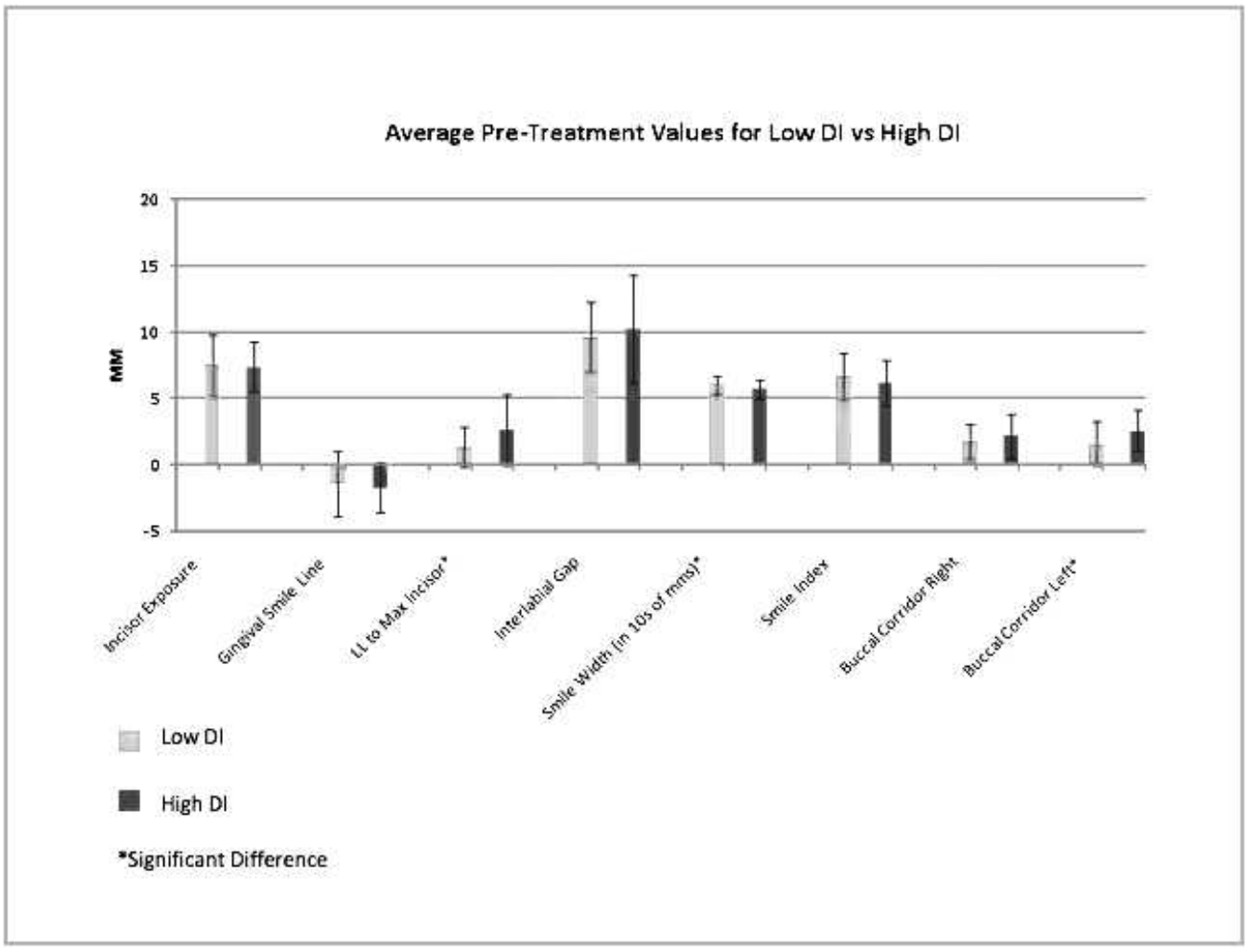

Figure 7. Comparison of pretreatment smile esthetics for mild and severe malocclusions.

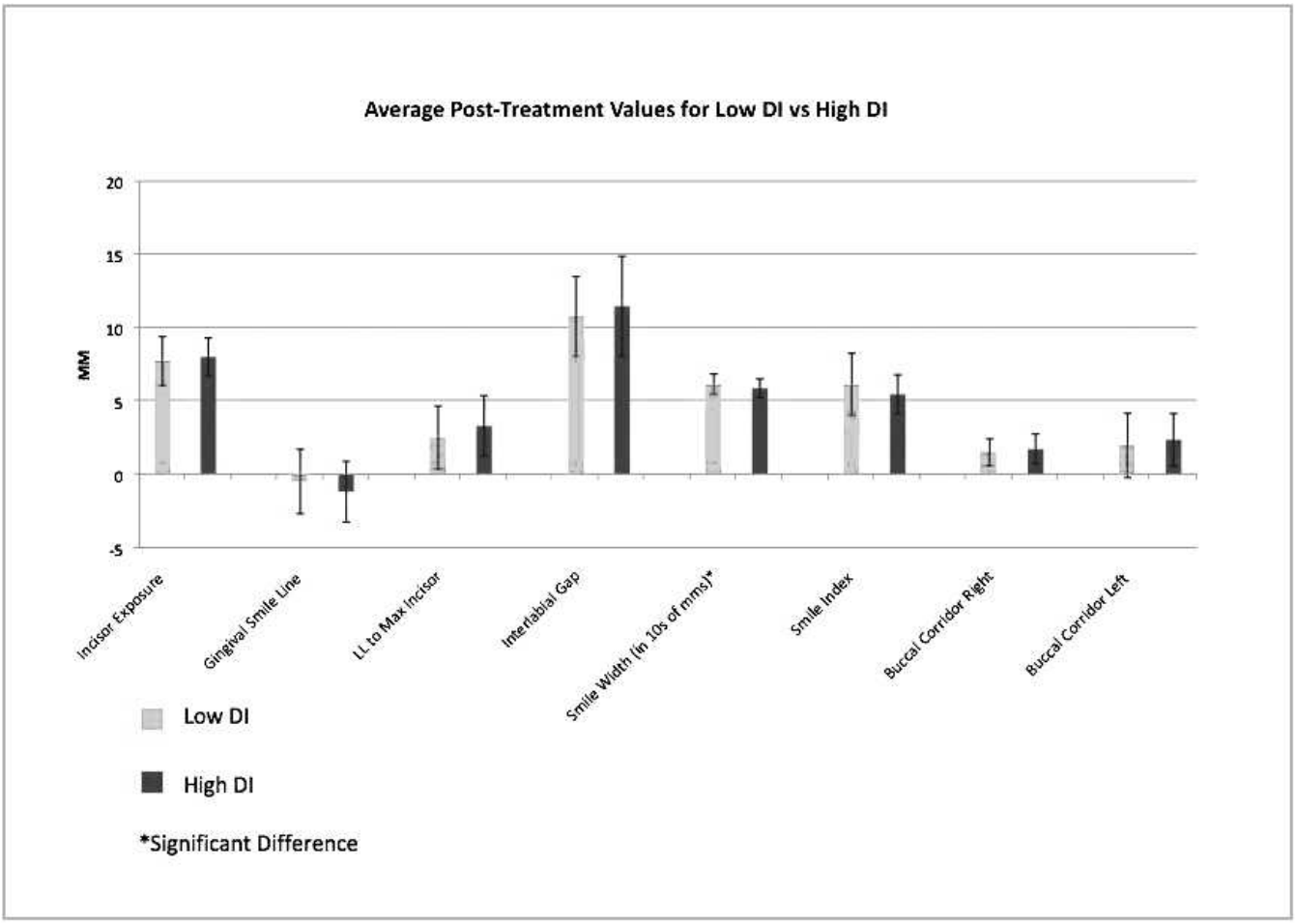

Figure 8. Comparison of posttreatment smile esthetics for mild and severe malocclusions.

pretreatment to posttreatment? (2) Were there different pretreatment to posttreatment changes between the low-DI and the high-DI groups? (3) Was the baseline DI score correlated with any change in smile mesh measurements?

The distributions of the pretreatment variables, posttreatment variables, and the differences between the pre- and posttreatment variables were normal, so parametric (paired *t*-tests) were performed to determine the significance between the low- and high-DI groups. A Wilcoxon signed rank test was performed to assess changes in the smile arc from pretreatment to posttreatment; these categories were coded as consonant or nonconsonant. Additionally, baseline malocclusion severity scores (DI) were correlated with changes in each of the smile mesh variables using a Spearman rank correlation.

The average pretreatment smile characteristics measured for the subjects in the low-DI and high-DI groups showed significant differences in the vertical measure of the maxillary incisor to the superior aspect of the lower lip and the horizontal measure of the width of the smile, as well as the width of the buccal corridor. The severe malocclusion group initially had significantly more incisor exposure, a smaller smile width, and a larger buccal corridor than the mild malocclusion group (Figure 7).

The average posttreatment smile characteristics measured for the subjects in the low-DI and high-DI groups showed significant differences only in the horizontal measure of the width of the smile. After successful orthodontic treatment, the severe malocclusion group still had a smaller smile width than the mild malocclusion group (Figure 8).

The average values for eight smile characteristics were analyzed prior to treatment and after successful completion of orthodontic treatment in both malocclusion groups. These descriptive statistics (Figures 9 and 10) were indicative of trends, although no significant differences were found for any of the variables.

The smile arc evaluation for the subjects in the low-DI and high-DI groups indicated that both the mild and severe malocclusion groups had an increase in smile

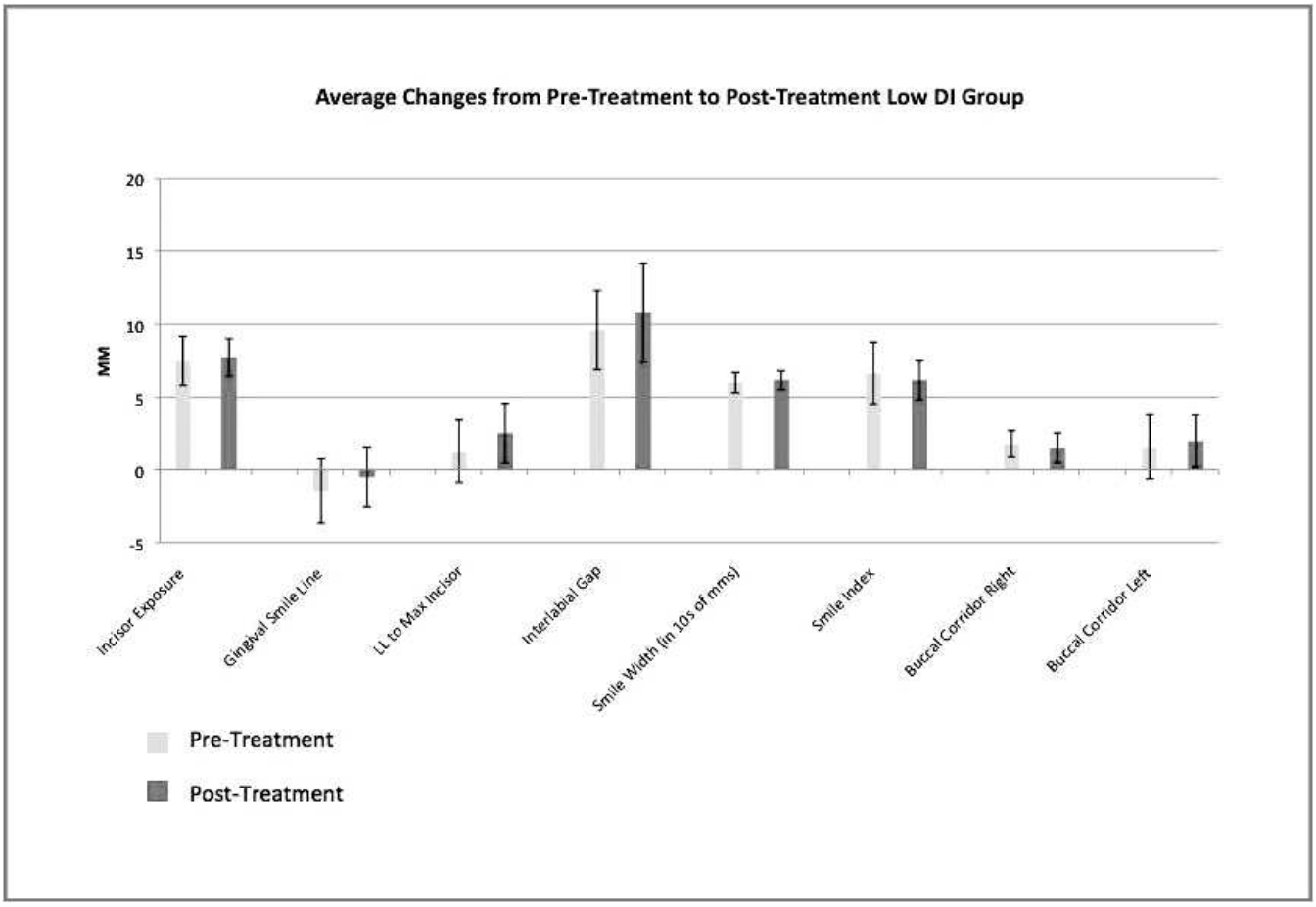

Figure 9. Smile esthetic changes in mild malocclusions.

consonance following orthodontic treatment. The mild malocclusion group improved from 68% smile consonance pretreatment to 77% consonance posttreatment, while the severe malocclusion group improved from 55% to 85% in smile consonance.

A Spearman correlation test indicated that the initial DI did not correlate to treatment-induced changes in any of the eight smile characteristics.

DISCUSSION

In this study, both the mild malocclusion and severe malocclusion groups showed increases in incisor exposure after successful orthodontic treatment. The average smile line prior to treatment for both groups was below the gingival margin of the incisors, giving a negative value for the gingival smile line measurement. By increasing incisor exposure, successful orthodontic treatment brought the gingival smile line values of both groups closer to zero (Figures 9 and 10). This represented an improvement in the patients' smiles and is in agreement with studies that found that the most attractive smiles have congruence of the gingival smile line at the gingival margin of the upper central incisors.[9,13,14]

The level of the smile line can be affected by the musculature and skeletal anatomy of individual patients, which can limit the extent of improvement with orthodontics alone.[25] In this study, the smile line did improve for both groups, but the average levels after successful orthodontic treatment were still slightly below the gingival margin, which may not be optimal.[5,15,22,23] It should be noted that careful analysis of the incisal display is an important diagnostic criterion when deciding which anterior teeth should be intruded to correct a deep overbite.

Smile width was the only variable that differed significantly between the low-DI group and the high-DI group, both before and after orthodontic treatment. The mild malocclusion group had a wider smile than the more severe malocclusion group. The smile width increased, while, in general, the buccal corridor space decreased for both the mild and severe malocclusion groups following successful orthodontic treatment. This resulted in a broader smile with less negative space.[21]

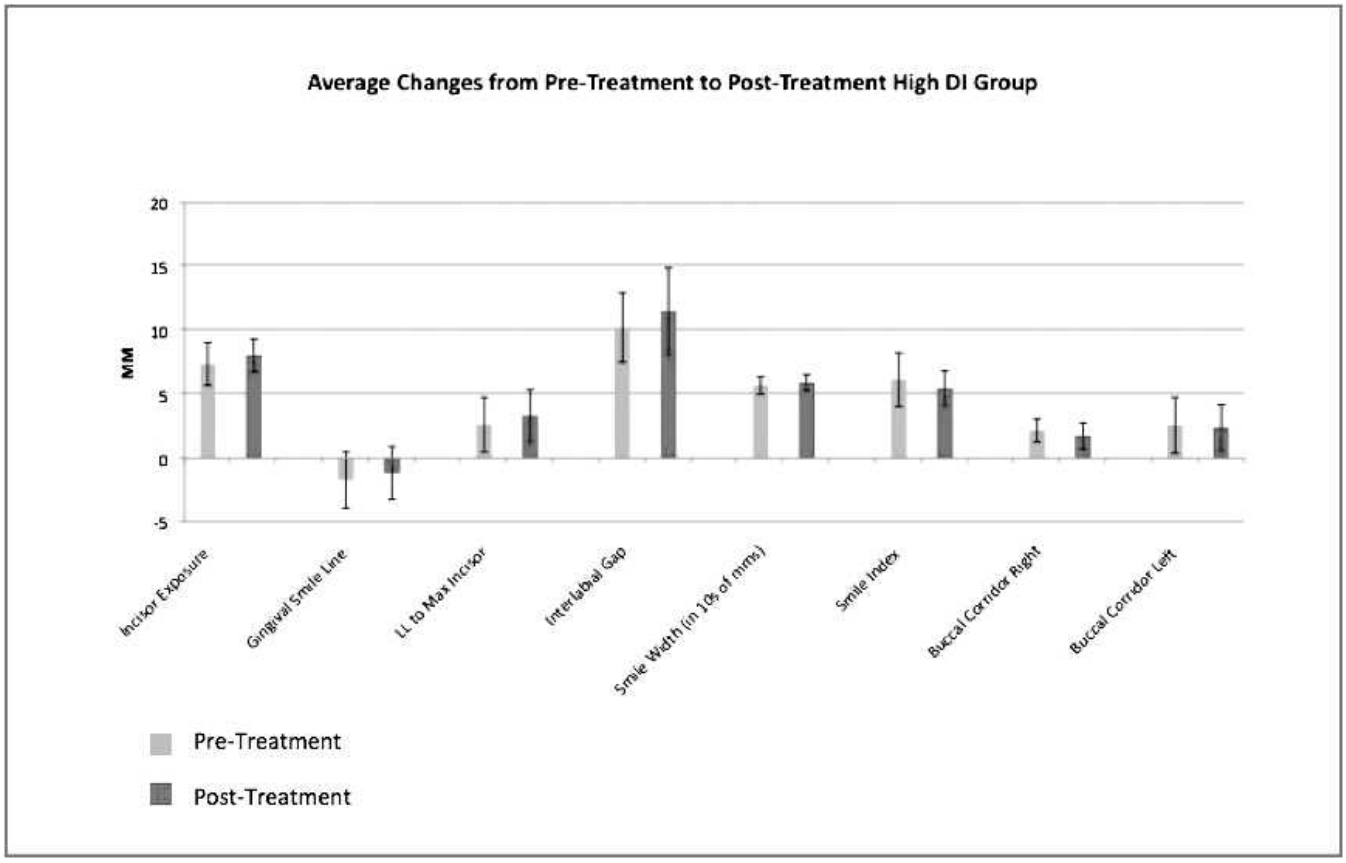

Figure 10. Smile esthetic changes in severe malocclusions.

In both groups, the interlabial gap increased following treatment, but proportionally less than the increase in smile width. This led to lower smile indices posttreatment. The lowering of the smile index in both groups could suggest that orthodontic treatment had an aging effect on the smile. Many previous studies have indicated that posed smiles with lower smile indices appear less youthful.[5,13,15–17] These results suggest that orthodontists should take care to avoid overintrusion of the maxillary incisors, thus increasing the distance from lower lip to maxillary incisal edge and adversely affecting smile esthetics.

There were more consonant smiles following successful orthodontic treatment in both malocclusion groups. However, the mild malocclusion group evidenced a lower percentage of improvement in smile consonance than the high-DI group. Both groups experienced these positive changes after treatment and should be seen as an esthetic success, since many studies have reported that both orthodontists and laypeople prefer consonant smile arcs.[9,19,24,25] The larger proportional improvement seen in the high-DI group, while not statistically significant, does suggest that dramatic smile improvements can be achieved more frequently in patients with more severe initial malocclusions.

CONCLUSIONS

- Smile esthetics is improved by orthodontic treatment regardless of the initial severity of the malocclusion.
- Both the low-DI and high-DI groups demonstrated: (1) improved incisor exposure, (2) an improved gingival smile line, (3) an increase in smile width, (4) a decreased buccal corridor space, and (5) an improvement in smile consonance.
- Patients with more complex orthodontic issues and their counterparts with minor malocclusions benefitted equally from treatment in terms of their smile esthetics.

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