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# The effect of increased overjet on the magnitude and reproducibility of smiling in adult females

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SUMMARY The objective of this study was to determine if increased overjet (greater than 6 mm) influences the magnitude and reproducibility of natural smile and maximal smile in Caucasian adult females. Twenty adult females with an increased overjet (6–10 mm) and 20 control adult females (overjet 2–4 mm) with no history of orthodontic treatment volunteered to participate. The mean age in the control group was 30.1 ± 6.4 years and the mean age in the test group was 31.9 ± 10.8 years. Three-dimensional stereophotogrammetric images were captured of each subject for three expressions: at rest, natural smile, and maximal smile. The images were recorded twice on two separate occasions, 6 weeks apart. Images were landmarked and a partial ordinary Procrustes superimposition was used to adjust for the differences in head posture between the same expressions. The magnitude of movement relative to the rest position, averaged over all the landmarks, was calculated and compared between the groups using analysis of variance (linear mixed-effects model); the intra- and inter-session reproducibility of both expressions was assessed. There was greater mean movement, averaged over all the landmarks, in the control group than in the increased overjet group for both natural smile and maximal smile ($P = 0.0068$). For these expressions, there were no statistically significant differences in reproducibility within sessions ($P = 0.5403$) or between sessions ($P = 0.3665$). Increased overjet had a statistically significant effect on the magnitude of smiling but did not influence the reproducibility of natural or maximal smile relative to controls.

## Introduction

Smiling is a gesture unique to humans (Matthews, 1978). Associated with friendliness, agreement, contentment, and sociability (Tjan *et al.*, 1984), smiling is pertinent in the evaluation of facial attractiveness (Kerns *et al.*, 1997). As an aesthetic smile is a primary treatment goal in both orthodontic and surgical orthodontic treatment (Sarver, 2001), the interplay between the teeth and lips at rest, during function, and facial expression should be incorporated in diagnosis (Sarver and Ackerman, 2003; van der Geld *et al.*, 2007).

Smile aesthetics are a major impetus for seeking orthodontic treatment (Baldwin, 1980) with many patients qualifying for state funding as a consequence of increased overjet (Lindauer *et al.*, 1988). This occlusal feature is a predictor of reduced facial attractiveness (O'Brien *et al.*, 2009) and increased levels of low self-perception (Johnston *et al.*, 2010). Although different types of smiles have been recognized (posed, strained, natural, spontaneous, open or closed, and half smiles), the natural (spontaneous) and maximal (posed) smiles have attracted most orthodontic interest (Ekman *et al.*, 1990; Paletz *et al.*, 1994; Peck and Peck, 1995). A variety of techniques have been used to assess smile aesthetics including photographs, video, model scanning, radiographs, stereophotogrammetry, and clinical assessment (Rigsbee *et al.*, 1988; Ferrario *et al.*, 1996; Wong *et al.*, 2005; De Castro *et al.*, 2006; Fudalej, 2008; Sforza *et al.*, 2008). For quantitative assessment, landmarks are either placed onto the face before imaging (Johnston *et al.*, 2003; Sawyer *et al.*, 2009) or on the images (Strauss *et al.*, 1997; Holberg *et al.*, 2006). Variability has been noted in smile reproducibility (Ackerman *et al.*, 1998; Frey *et al.*, 1999) with the natural and maximal smile being less reproducible than rest position (Johnston *et al.*, 2003), which has been shown to be the most reproducible (Johnston *et al.*, 2003; Sawyer *et al.*, 2009).

Inter-session reproducibility has been noted to be lower than intra-session reproducibility (Trotman *et al.*, 1998) although this may be subject specific. Open mouthed smile has been shown to have large inter-session variability (Sawyer *et al.*, 2009). Inter-session reproducibility has greater relevance in orthodontics than intra-session reproducibility due to the need to make sequential assessments of smiling throughout orthodontic and surgical orthodontic management.

Factors influencing smiling include the maxillary and mandibular skeletal relationships (Trotman and Faraway, 2004), height and length of the upper lip (van der Geld *et al.*, 2007), age (Houstis and Kiliaridis, 2009), race (Sabherwal *et al.*, 2009), and gender (Johnston *et al.*, 2003). Moreover, Bailey *et al.* (2001) noted that females presenting at a dentofacial clinic perceive a much greater demand for treatment in comparison to males. The increased focus on smiling as an outcome measure of dentofacial attractiveness, especially in adult females, has not been assessed objectively. Therefore, the objective of this study was to determine in a Caucasian adult female sample if increased overjet (greater than 6 mm) influences the magnitude and reproducibility of natural and maximal smile compared to controls (overjet 2–4 mm).

## Materials and methods

Ethical approval was obtained from the local medical ethics committee. Using the data from Johnston *et al.* (2003), a sample size of 30 subjects with 15 in each of the test and control groups would have a power of 80 per cent to detect differences of 0.5 mm between similar expressions between groups where $P = 0.05$. An additional five subjects were recruited per group to allow for possible sample size attrition. Caucasian adult females of Irish origin greater than 18 years, with an overjet between 6 and 10 mm for the test group and between 2 and 4 mm for the control group, were invited to participate. Subjects who were non-Caucasian, male with congenital orofacial clefting or subjects with suspected or identifiable syndromes, previous facial surgery, trauma, facial burns, muscular disorders, or palsy (including botulinum toxin injections and dermal fillers) of the facial region, anterior open bite, and gross facial asymmetry were excluded.

A stereophotogrammetric camera system (www.di3d.com; Ayoub *et al.*, 1998), re-calibrated for each session, was connected to a Dell Dimension 8400 PC with images captured using diCapture™ software. This system has been shown to have an accuracy of 0.1 mm (Johnston et al., 2001). The cameras simultaneously recorded a pair of images corresponding to the left and right side of the face. A test shot was taken to familiarize the subject before the study images were captured. One operator, experienced in three-dimensional (3D) image capture, recorded the following facial expressions after giving each subject identical verbal and visual instructions (Zachrisson, 1998):

1. Rest position
   - Say ‘Mississippi’ then swallow and say ‘N’.
2. Natural smile
   - Bite teeth together gently and say ‘Cheese’
3. Maximal smile
   - Bite teeth gently together and smile maximally

Subjects practiced expressions twice before each image was taken. After a 15 minute rest period, each expression was captured a second time within the session. Each subject returned approximately 6 weeks later for a further session, giving a total of 12 images per subject.

The first image for each subject was aligned with an axis centred on the calibration target and subsequent images were aligned with this. Using diView4™ landmarking tool, the 3D coordinates for each landmark (Figure 1, Table 1) were recorded for each image by an experienced observer (Farkas *et al.*, 1980). To adjust for variations in head posture between expressions for each subject, a partial ordinary Procrustes superimposition was undertaken using stable upper facial landmarks (right and left exocanthion, right and left endocanthion, right and left mid pupil, glabella, and forehead; Hajeer *et al.*, 2004).

A random 10 per cent sample of images were re-landmarked by the same operator to assess intra-observer

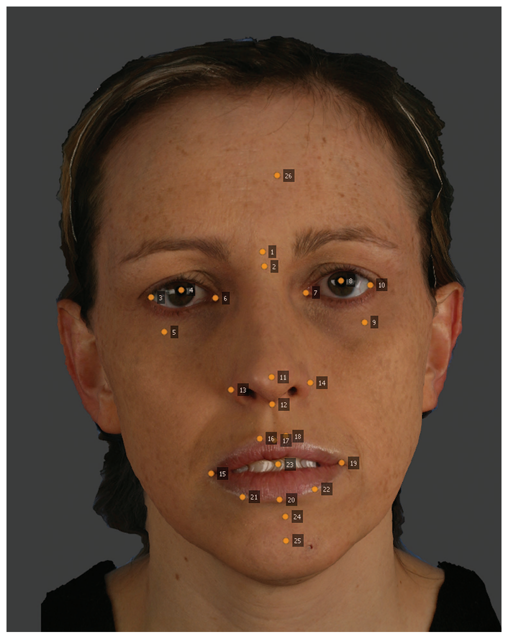

**Figure 1** Landmark definitions: 1. glabella (most prominent midline point between eyebrows), 2. soft tissue nasion (point in the midline of the nasal root), 3. exocanthion right (outer most point on commissure of right eye fissure), 4. mid pupil right (centre point of right pupil), 5. orbitale right (lowest point on lower margin of right orbit), 6. endocanthion right (inner most point on commissure of right eye fissure), 7. endocanthion left (inner most point on commissure of left eye fissure), 8. mid pupil left (centre point of left pupil), 9. orbitale left (lowest point on lower margin of left orbit), 10. exocanthion left (outer most point on commissure of left eye fissure), 11. pronasale (most protruded point of apex nasi identified from lateral view), 12. subnasale (midpoint of columella), 13. subalare right (labial insertion of right alare base), 14. subalare left (labial insertion of left alare base), 15. cheilion right (outer most point of right lip commissure), 16. crista philtre right (point on right elevated margin of philtrum just above vermilion line), 17. labiale superius (midpoint on upper vermilion border), 18. crista philtre left (point on left elevated margin of philtrum just above vermilion line), 19. cheilion left (outer most point of left lip commissure), 20. labiale inferius (lower border of lower lip), 21. lower lip right (point midway between cheilion right and labiale inferius), 22. lower lip left (point midway between cheilion left and labiale inferius), 23. stomion (point at intersection of vertical facial midline and horizontal labial fissure—at rest photos only), 24. sublabiale (the mentolabial ridge), 25. pogonion (most anterior midpoint on chin), 26. forehead (unique fixed point for each patient).

**Table 1** Landmark definitions.

| Landmark name | Definition |
|---|---|
| 1. Glabella | Most prominent midline point between eyebrows |
| 2. Soft tissue nasion | Point in the midline of the nasal root |
| 3. Exocanthion right | Outer most point on commissure of right eye fissure |
| 4. Mid pupil right | Centre point of right pupil |
| 5. Orbitale right | Lowest point on lower margin of right orbit |
| 6. Endocanthion right | Inner most point on commissure of right eye fissure |
| 7. Endocanthion left | Inner most point on commissure of left eye fissure |
| 8. Mid pupil left | Centre point of left pupil |
| 9. Orbitale left | Lowest point on lower margin of left orbit |
| 10. Exocanthion left | Outer most point on commissure of left eye fissure |
| 11. Pronasale | Most protruded point of apex nasi (identified from lateral view) |
| 12. Subnasale | Midpoint of columella |
| 13. Subalare right | Labial insertion of right alare base |
| 14. Subalare left | Labial insertion of left alare base |
| 15. Cheilion right | Outer most point of right lip commissure |
| 16. Crista philtre right | Point on right elevated margin of philtrum just above vermilion line |
| 17. Labiale superius | Midpoint on upper vermilion border |
| 18. Crista philtre left | Point on left elevated margin of philtrum just above vermilion line |
| 19. Cheilion left | Outer most point of left lip commissure |
| 20. Labiale inferius | Lower border of lower lip |
| 21. Lower lip right | Point midway between cheilion right and labiale inferius |
| 22. Lower lip left | Point midway between cheilion left and labiale inferius |
| 23. Stomion | Point at intersection of vertical facial midline and horizontal labial fissure (at rest photos only) |
| 24. Sublabiale | The mentolabial ridge |
| 25. Pogonion | Most anterior midpoint on chin |
| 26. Forehead | Unique fixed point for each patient |

reproducibility by comparing the 3D coordinate values with the originals (Johnston *et al.*, 2003).

*Statistical analysis*

The movement data (the square root of the sum of the squared difference in the position of the points in each plane between rest and natural smile and rest and maximal smile) and their reproducibility were analysed using linear mixed-effects models for repeated measures after logarithmic transformations. The distributions of movements were right-skewed and the logarithmic transformation was, therefore, necessary to normalize the residuals of the linear mixed-effect models. Normally distributed residuals are a necessary condition for the application of these models. Group (increased overjet or control), session (first or second), capture within session (first or second), and expression (natural smile or maximal smile) were included as fixed factors. The subject was included as a random effect in all models. The two-way interactions between the fixed factors were included in all models. A first-order auto-regressive correlation structure was used to model the correlation for the repeated measurements. An analysis was performed for the averages over all landmarks and for each landmark individually. Residual analyses were performed for all models to confirm their adequacies. All statistical analyses were performed in SAS® (version 9.1.3; www.sas.com, Cary, North Carolina, USA).

## Results

*Sample characteristics*

Forty Caucasian females with a mean age of 31.0 years (SD = 8.3) volunteered. Of these, 20 test subjects [mean age = 31.9 years (SD = 10.8)] had an overjet greater than 6 mm [mean = 8.1 mm (SD = 1.8)] and 20 control subjects had a mean age of 30.1 years (SD = 6.4) with an overjet of 2–4 mm [mean = 2.4 mm (SD = 0.9)].

*Intra-observer reproducibility and landmark identification error*

Intra-observer reproducibility was determined to be acceptable ($P > 0.05$) when the geometric distances of the random 10 per cent of re-landmarked images were compared with the originals. Across all the images, the average landmark identification error was 0.57 mm.

*Effect of overjet on magnitude of natural and maximal smile*

In the test group, the mean movement of the landmarks from rest to natural smile was 2.57 mm (SD = 1.09) and from rest to maximal smile was 3.68 mm (SD = 1.15). In the control group, the mean landmark movement for the similar parameters was 3.19 mm (SD = 1.23) and 4.30 mm (SD = 1.12), respectively (Table 2). The average movement was greater in the control group than in the test group ($P$ = 0.0068); this difference was similar for both rest to natural and rest to maximal smile (0.62 mm; $P$ = 0.3673) and was similar both within sessions ($P$ = 0.0714) and between sessions ($P$ = 0.2413). These results are shown in Table 3.

The magnitude of movement varied across landmarks and was significantly different between the test and control groups for glabela, orbitale left, exocanthion left, subalare right, subalare left, cheilion left, sublabiale, and pogonion ($P < 0.05$; Table 4). In all cases, the differences between the test and control groups were similar for both expressions ($P > 0.05$). The majority of movement occurred within the lower facial landmarks, with the upper facial landmarks moving significantly less during smiling. There was greater movement in both upper and lower facial landmarks in maximal than natural smile for each group.

*Intra-session and inter-session reproducibility*

There was no statistically significant difference between captures within sessions ($P$ = 0.5403) or between sessions ($P$ = 0.3665; Table 3).

**Table 2** Mean movements (averaged over landmarks) from rest to natural smile and rest to maximal smile.

| | | | Group | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Test | | | Control | | |
| | | | *N* | Mean | SD | *N* | Mean | SD |
| Expression | Session | Capture | | | | | | |
| Rest to natural smile | 1 | A | 20 | 2.49 | 1.09 | 20 | 3.02 | 1.04 |
| | | B | 20 | 2.71 | 0.97 | 20 | 3.23 | 1.15 |
| | | Total | 40 | 2.60 | 1.02 | 40 | 3.12 | 1.09 |
| | 2 | A | 20 | 2.36 | 0.99 | 20 | 3.45 | 1.48 |
| | | B | 20 | 2.72 | 1.31 | 20 | 3.05 | 1.23 |
| | | Total | 40 | 2.54 | 1.16 | 40 | 3.25 | 1.36 |
| | Total | A | 40 | 2.42 | 1.03 | 40 | 3.23 | 1.28 |
| | | B | 40 | 2.71 | 1.14 | 40 | 3.14 | 1.18 |
| | | Total | 80 | 2.57 | 1.09 | 80 | 3.19 | 1.23 |
| Rest to maximal smile | 1 | A | 20 | 3.81 | 1.02 | 20 | 4.24 | 1.08 |
| | | B | 20 | 3.89 | 1.27 | 20 | 4.46 | 1.48 |
| | | Total | 40 | 3.85 | 1.14 | 40 | 4.35 | 1.29 |
| | 2 | A | 20 | 3.41 | 1.14 | 20 | 4.54 | 0.89 |
| | | B | 20 | 3.62 | 1.20 | 20 | 3.95 | 0.92 |
| | | Total | 40 | 3.51 | 1.16 | 40 | 4.25 | 0.94 |
| | Total | A | 40 | 3.61 | 1.09 | 40 | 4.39 | 0.99 |
| | | B | 40 | 3.75 | 1.23 | 40 | 4.20 | 1.24 |
| | | Total | 80 | 3.68 | 1.15 | 80 | 4.30 | 1.12 |

**Table 3** Analysis of mean movements (averaged over landmarks). Num DF, numerator degrees of freedom; Den DF, denominator degrees of freedom; Pr > F, probability associated with the *F*-value.

| Type 3 tests of fixed effects | | | | |
|---|---|---|---|---|
| Effect | Num DF | Den DF | *F*-value | Pr > F |
| Group | 1 | 271 | 7.45 | 0.0068 |
| Session* | 1 | 271 | 0.82 | 0.3665 |
| Expression | 1 | 271 | 131.01 | <0.0001 |
| Capture** | 1 | 271 | 0.38 | 0.5403 |
| Group × session | 1 | 271 | 1.38 | 0.2413 |
| Group × expression | 1 | 271 | 0.82 | 0.3673 |
| Group × capture | 1 | 271 | 3.28 | 0.0714 |
| Session × expression | 1 | 271 | 0.50 | 0.4815 |
| Session × capture | 1 | 271 | 1.21 | 0.2731 |
| Expression × capture | 1 | 271 | 1.08 | 0.2989 |

*Session: inter-session reproducibility.
**Capture: intra-session reproducibility.

## Discussion

This study evaluated the effect of overjet on the magnitude and reproducibility of smiling in adult females. We chose females rather than males in view of the increased awareness of orthodontic treatment need in the former group (Bailey *et al.,* 2001). Overjet, in preference to incisor classification, was used for subject selection with the sample size being consistent to that used in similar investigations (Johnston *et al.*, 2003; Houstis and Kilaridis, 2009). Only volunteers with an increased overjet greater than 6 mm were selected for the test group as these are included in the Dental Heath Component Grades of 4 and 5 in the Index of Orthodontic Treatment Need which represent 'need' and 'great need' for treatment, respectively (Brook and Shaw, 1989).

While the underlying skeletal pattern was not determined, it is likely that any bias arising from this would be low (Trotman and Faraway, 2004). Similarly, subjects were not stratified according to soft-tissue characteristics (including lip length and morphology among others). In order to minimize other contributors to bias, the conditions for image capture were standardized. Consistency of image capture and landmarking were maintained throughout the study with an individual operator used to record images and place landmarks. In addition, landmarks were identified directly from the 3D image rather than from landmarks placed with a fine pencil on subjects' faces (Johnston *et al.*, 2003); the former process allowed the intra- and inter-session reproducibility of each expression to be assessed.

Stereophotogrammetry used to capture images is a safe, fast, accurate, and reproducible method (Hajeer *et al.*, 2002; Ayoub *et al.*, 2003). The mean landmark identification error found in this study is comparable to other investigations using 3D imaging (Moss *et al.*, 1987; Trotman *et al.*, 1998) and is below the level of 0.79 mm found by Ayoub *et al.* (2003) but was marginally higher than the value of 0.49 mm found by Johnston *et al.* (2003).

A partial ordinary Procrustes superimposition using the upper facial landmarks for image alignment and orientation was employed. This approach was similar to that reported

**Table 4** Analysis of individual landmarks—list of significant effects.

| Landmark | Significant effects | *P* value |
|---|---|---|
| Glabella | Group | 0.0161 |
| | Expression | 0.0228 |
| | Session × capture | 0.0348 |
| Soft tissue nasion | Expression | 0.0098 |
| Exocanthion right | Expression | <0.0001 |
| Mid pupil right | None | — |
| Orbitale right | Expression | <0.0001 |
| Endocanthion right | Expression | 0.0050 |
| Endocanthion left | None | — |
| Mid pupil left | Expression | 0.0043 |
| Orbitale left | Group | 0.0129 |
| | Expression | <0.0001 |
| Exocanthion left | Group | 0.0297 |
| | Expression | <0.0001 |
| | Group × session | 0.0321 |
| Pronasale | Expression | 0.0002 |
| Subnasale | Expression | <0.0001 |
| | Group × session | 0.0252 |
| Subalare right | Group | 0.0008 |
| | Expression | <0.0001 |
| Subalare left | Group | 0.0039 |
| | Expression | <0.0001 |
| | Session × capture | 0.0122 |
| Cheilion right | Expression | <0.0001 |
| | Group × session | 0.0231 |
| Crista philtre right | Expression | <0.0001 |
| Labiale superius | Expression | <0.0001 |
| Crista philtre left | Expression | <0.0001 |
| Cheilion left | Group | 0.0167 |
| | Expression | <0.0001 |
| Labiale inferius | Expression | <0.0001 |
| | Group × capture | 0.0068 |
| Lower lip right | Expression | <0.0001 |
| | Group × capture | 0.0218 |
| Lower lip left | Expression | <0.0001 |
| Sublabiale | Group | 0.0264 |
| | Expression | 0.0004 |
| | Capture | 0.0254 |
| | Group × capture | 0.0013 |
| Pogonion | Group | 0.0411 |
| | Expression | 0.0012 |
| | Group × capture | 0.0042 |

by Johnston *et al.* (2003) who used the upper facial points to align images in order to eliminate any difference in head posture between captures.

### *Effect of overjet on magnitude of natural and maximal smile*

We found that increased overjet had a statistically significant effect on the magnitude of movement during smiling ($P = 0.0068$). There was greater mean movement in the control group for rest to natural and maximal smile, which was consistent across all captures and sessions for both expressions. This difference between the test and control groups could arise due to social conditioning of the subject with an increased overjet who may try to mask this feature in social situations by not smiling maximally (Badran, 2010). The magnitude of movement was greater in the lower facial landmark area than in the upper landmark area for both groups. The range of movement of circumoral musculature and the capacity for additional movement in the lower face may well contribute to the increased magnitude of movement in these areas in comparison to the upper facial landmarks. This finding is consistent with Holberg *et al.* (2006) who reported similar results using a two-dimensional investigation of rest and smile and with the findings of the study by Trotman *et al.* (1998), which used 3D technology to investigate facial animation.

### *Intra-session reproducibility*

We found intra-session reproducibility to be good for both test and control groups. We found marginally less variability of movement in the test group than the control group. This is similar to the findings of previous studies (Wood *et al.*, 1994; Trotman *et al.*, 1996; Holberg *et al.*, 2006). While some studies have found intra-session reproducibility to be in the region of 1 mm (Frey *et al.*, 1994; Strauss *et al.*, 1997), Johnston *et al.* (2003) found the mean intra-session reproducibility of five expressions to be 1.2 mm. In accordance with Johnston *et al.* (2003), the reproducibility of individual landmarks was specific to the expression (Table 4).

### *Inter-session reproducibility*

We found no statistically significant differences between sessions within each group. Johnston *et al.* (2003) also noted greater inter-session reproducibility in females than in males, whereas high inter-session variability with an open mouth smile has been found in an investigation of female subjects using an optical tracking system (Hontanilla and Aubá, 2008) and in a mixed male and female group (Sawyer *et al.*, 2009) when studied using stereophotogrammetry.

The findings of this study have implications for the orthodontic and orthognathic management of female patients with an increased overjet. Clinicians need to be aware that increased overjet while affecting the magnitude of facial movement on smiling does not affect its reproducibility. This supports the robustness of 3D recording of smiling taken in advance of and throughout treatment. Assessment, however, of smiling magnitude and reproducibility in adult females following correction of an increased overjet requires further investigation.

## Conclusions

Increased overjet had a statistically significant effect on the magnitude of smiling but did not influence the reproducibility of natural or maximal smile relative to controls.

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