Changes in the Soft Tissue Facial Profile Following Orthodontic Extractions: A Geometric Morphometric Study

Dr. G.D. Singh D.D.Sc. Ph.D. B.D.S., Linette Maldonado, Dr. BS Thind BDS MSc FFD RCSI M Orth

GD Singh DDSc PhD BDS
Associate Professor
University of Puerto Rico, USA

Linette Maldonado
Undergraduate student
University of Puerto Rico, USA

BS Thind BDS MSc FFD RCSI M Orth
Orthodontist
Royal Aberdeen Hospital, UK

Correspondence:
Dr. G.D. Singh D.D.Sc. Ph.D. B.D.S.
Associate Professor
Center for Craniofacial Disorders
Office A-570
School of Medicine
University of Puerto Rico
PO Box 365067
San Juan, PR 00936-5067 USA

Tel: 787 758 2525 x 1503
Fax: 787 767 0788
Email: gdsingh@rcm.upr.edu

Objectives: The aim of this study is to test the null hypothesis that changes in soft tissue facial profile in children who undergo orthodontic treatment, using either an extraction or non-extraction technique, do not differ.

Design: Longitudinal, retrospective.

Setting and Sample Population: San Juan, PR and Aberdeen, UK. Fifty-eight consecutively treated children using fixed appliances with a mean age of 13.2 (± 2.1) years.

Experimental variable: Extraction of the upper and lower, first or second premolars.

Outcome measures: The mean pre- and post-treatment, extraction and non- extraction configurations were compared using finite-element scaling analysis (FESA), incorporating a thin-plate spline interpolation.

Results: Post-treatment the two groups differed statistically in the premaxillary region ($p < 0.05$) with the non-extraction group being relatively larger in that region by 25%. For the non-extraction group after treatment, localized increases in relative size in the naso-maxillary region size of 25% ($p < 0.01$) were present. For the extraction group after treatment, a non-significant reduction in relative size of 15% was localized in the putative bicuspid area.

Conclusion: Soft tissue facial differences in non-extraction and extraction cases prior to treatment may be accentuated following orthodontic treatments that elect non-extraction or extraction protocols. Robust diagnosis and treatment planning, incorporating the judicious use of extractions if appropriate, may yield optimal orthodontic outcomes.

Figure1 Soft tissue landmarks employed in this study.

SfN	*Soft nasion: maximum concavity overlying the frontonasal suture*
SfRo	*Soft rhinion: most prominent point on the anterior tip of the nose*
Cm	*Columella: point of intersection of the nose with the philtrum of the upper lip*
LS	*Labrale superius: maximum midsagittal convexity on the upper lip*
LC	*Labial commissure: lateral angle of the mouth*
LI	*Labrale inferius: maximum midsagittal convexity on the lower lip*
SfPo	*Soft pogonion: most anterior point directly opposite pogonion*
CMJ	*Cervico-mental junction of submental region and the anterior border of the neck*
LCE	*Lateral canthus: lateral-most point on the lateral canthus of the eye*
PN	*Posterior nostril: junction of the alar of the nose and the nasolabial furrow*

Introduction

At the turn of the century, followers of Angle's "new school" believed that, if the teeth were in harmony, the face would be as well[1, 2]. Their belief was based on the notion that orthodontic appliances could induce osteogenesis, obviating the need for extractions. Others contended that bone could not be encouraged to grow beyond its inherent potential and, therefore, extractions were necessary to treat some malocclusions[3]. This debate is still ongoing. Some studies report that premolar extractions will compromise post-treatment esthetics by "dishing-in" the facial profile[4-6]. Conversely, other reports show no deleterious effects on the facial profile, or sub-optimal outcomes, when treatment is carried out using extractions followed by fixed appliances[7-9].

The overall changes in the facial appearance of young patients undergoing orthodontic therapy are the net result of growth and treatment[10]. Several methods have been used to evaluate these facial changes, including anthropometry[11], photogrammetry[12], computer imaging[13-14] and cephalometry[15-17]. Profiles views have been evaluated with cephalometric or photometric linear and angular measurements[18-19], combinations of metric, angular and proportional measurements[20-21] and the silhouette method [22-23]. To date, however, there is a dearth of studies investigating the effect of extraction or non-extraction orthodontic treatment on the facial profile using geometric morphometrics. Therefore, the aim of this study is to determine whether facial profile differences are discernible in children who underwent orthodontic treatment, using either an extraction or non-extraction technique. Rejection of the null hypothesis, that changes in soft tissue facial profile in children who undergo orthodontic treatment using extractions or non-extractions do not differ, will be based upon localization and quantification of statistical differences employing geometric morphometrics.

Materials and Methods

Sample

This present study was based on a total sample of 58 children with a mean age of 13.2 (± 2.1) years at the beginning of treatment, after

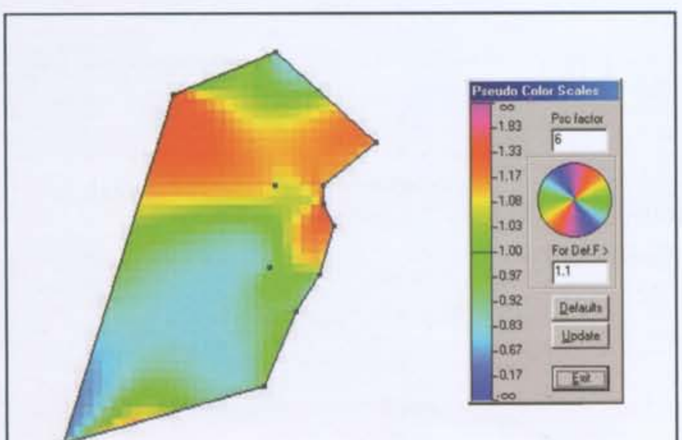

Figure 2 Pre- and post-treatment comparison of non-extraction means. The non-extraction cases relatively larger in the naso-maxillary region and premaxillary regions (red-orange coloration). Note the relative absence of a decrease in size in the putative bicuspid region.

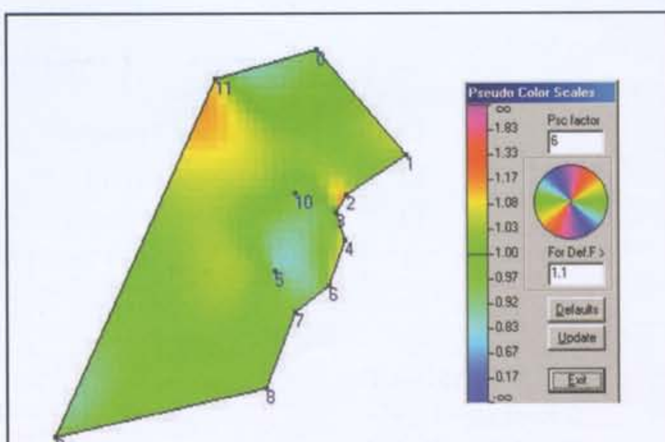

Figure 3 Pre- and post-treatment comparison of extraction means. Most of the configuration shows little change (green coloration) but note the small decrease in size localized in the putative bicuspid region (blue coloration).

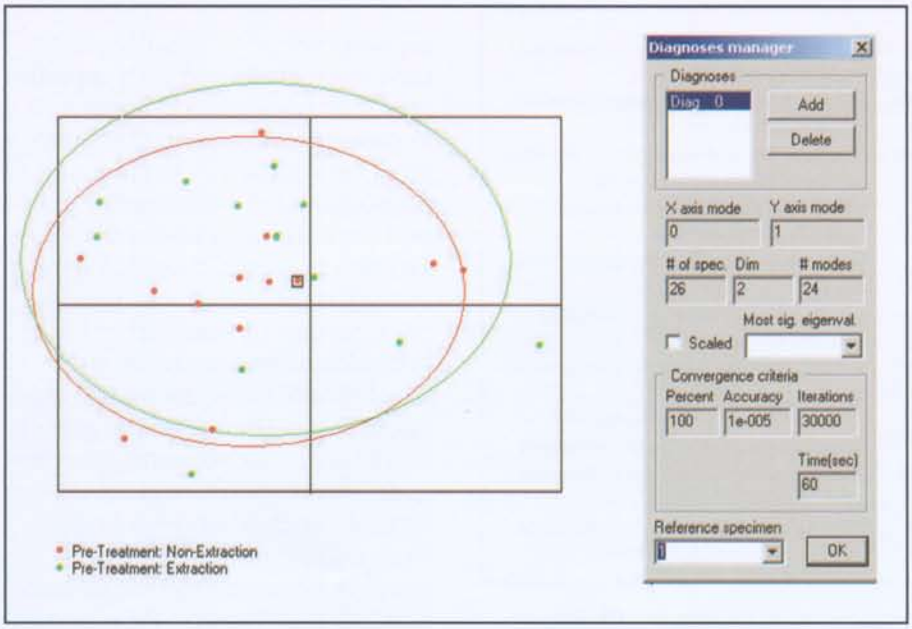

Figure 4 Using PCA, the non-extraction and extraction occupy similar shape spaces, using the first two eigenvalues, suggesting that the two samples were similar in shape prior to treatment.

obtaining ethical approval, informed consent and a signed HIPAA release form. Prior to treatment a standardized lateral photograph was taken in the natural head position for all patients, using the same camera and photographic settings, and this was repeated at the end of the active phase of treatment. All patients were treated by the same orthodontist (BST) using fixed appliances for all cases, with a mean treatment time of 24.7 (± 6.9) months. As a part of the treatment protocol deemed clinically appropriate for the patients requiring extractions, the upper and lower, first or second premolars were the teeth chosen for extraction. All decisions regarding extractions were made by the same orthodontist (BST) when deemed

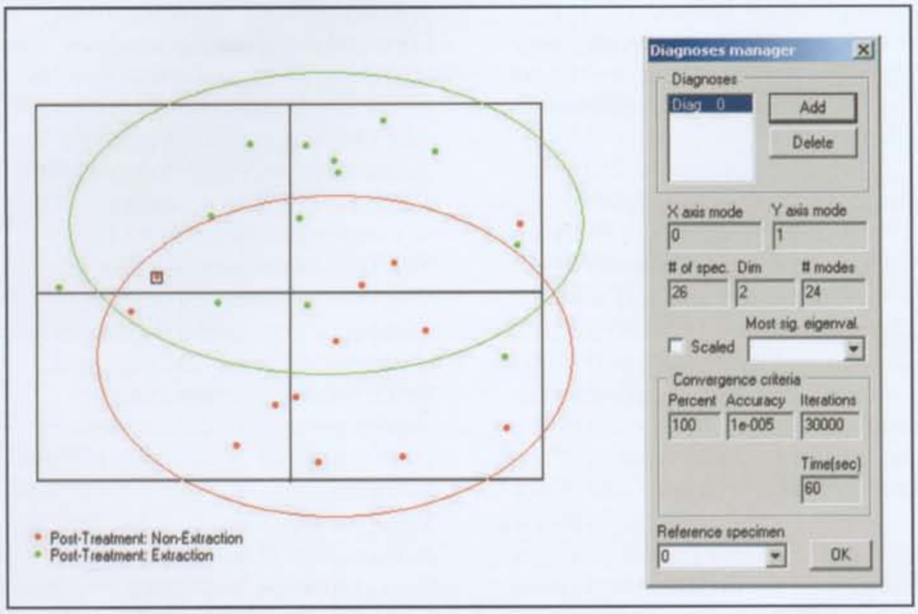

Figure 5 Using PCA, the first two eigenvalues separate the two samples more completely, based on their new shape information after treatment.

to be clinically appropriate. Exclusion criteria for the study were a history of previous orthodontic treatment, oral and/or maxillofacial surgery, any facial injury that resulted in hospital attendance, or any congenital craniofacial malformation. Inclusion criteria were a moderate Class II malocclusion with no vertical discrepancy.

All photographs were scanned and 15 soft tissue landmarks, which encompassed the anterior facial region (Fig. 1), were digitized in duplicate to minimize digitization errors, using MorphoStudio™ v. 2.0 software (www.morphostudio.com). Using this software, Procrustes superimposition was implemented to ensure that all configurations were scaled to an equivalent size and registered with respect to one another[24]. Thus, mean facial configurations were determined for both groups, and MorphoStudio™ software was used to compare the mean extraction and non-extraction configurations pre- and post-treatment.

Finite-element scaling analysis (FESA) was used to depict the clinical changes in terms of allometry (size-related shape-change)[25]. Using FESA, the change in form between the reference configuration and the final configuration is viewed as a continuous deformation, which can be quantified based on major and minor strains (principal strains). If the two strains are equal, the form change is characterized by a simple increase or decrease in size. However, if one of the principal strains changes in a greater proportion, transformation occurs in both size and shape. The product of the strains indicates a change in size if the result is not equal to 1. For example, a product >1 represents an increase in size equal to the remainder; 1.30 indicates a 30% increase. The products and ratios can be resolved for individual landmarks within the configuration and these can be linearized using a log-linear scale. For ease of interpretation, a pseudocolor-coded scale is deployed to provide a graphic display of size-change incorporating a thin-plate spline interpolation, using MorphoStudio™ software. Principal Components Analysis was used also to identify shape characteristics in the mode space before and after treatment. Finally, the oblique facial length from the lateral canthus of the eye to soft pogonion (Fig. 1) was measured for both groups, and mean lengths were subjected to t-tests.

Results

Unlike their statistical behavior prior to treatment, post-treatment the two groups differed statistically in the premaxillary region ($p < 0.05$). As well, the oblique length of the face from the lateral canthus of the eye to soft pogonion was significantly increased by 6% ($p < 0.05$) in the extraction group after treatment, but facial length did not differ in the non-extraction group after treatment.

For the non-extraction group after treatment (Fig. 2), localized increases in relative size were found in the naso-maxillary region by 25% ($p < 0.01$).

For the extraction group after treatment (Fig. 3), there were no statistically significant changes in the maxillo-mandibular regions, even though a reduction in relative size of 15% was localized in the oral area near the presumptive premolar region.

Finally, using PCA, it was found that the non-extraction and extraction two groups were similar in shape prior to treatment (Fig. 4) but after their respective treatment they are more completely separated, based on shape information (Fig. 5).

Discussion

The use of extractions in orthodontic protocols remains controversial[26] and even though the issue has been around since the 1960s, it still has not been resolved[46, 47]. The aim of this present study was to assess the impact on the facial profile of orthodontic extractions, using geometric morphometrics. Cephalometric (radiographic) data are not under investigation in this present study. Rather, this study focuses on soft tissue facial changes, because these are the features that patients recognize and identify with.

The most striking cephalometric findings are the considerable amount of variation in soft tissue change[36-37]. Earlier, it was suggested that hard and soft tissue change is due to a combination of growth and treatment, and their concordance is too complex to be assessed using simple, cephalometric analysis[38]. Indeed, others[39] cast doubt on the scientific validity of traditional cephalometric analyses. Therefore, in this present study we employed geometric morphometrics on lateral facial photographs. Our current findings indicated that, post-treatment, the two groups differed statistically in the premaxillary region ($p < 0.05$); the non-extraction group was relatively larger in that region by 25%, which may produce a relatively fuller facial profile (Fig. 4). For the extraction group after treatment (Fig. 3), a relative reduction in size of 15% was localized in the oral region near the presumptive premolar area, which may be associated with bicuspid extractions. As well, the oblique length of the face from the lateral canthus of the eye to soft pogonion was significantly increased ($p < 0.05$) in the extraction group after treatment by 6%, which may produce a relatively longer and less full facial profile. Thus, using geometric morphometric techniques on 2-D lateral photographs, localization and quantification of the effects of orthodontic bicuspid extraction/non-extraction was demonstrable. Taken together these current results support the contention that the choice of extractions or non-extraction may affect the final facial profile following orthodontic treatment.

Information obtained from geometric morphometrics is more robust than traditional cephalometric methods [48]. For example, Principal components analysis (PCA) can be used to compare different groups of patients, with specific characteristics. Normally a few modes (the principal components) are sufficient to describe all of the shapes approximately. Additionally, the points representing the shapes in the mode space are grouped according to their main characteristics. If PCA is applied and the two most significant modes are used to display results, Figures 4 and 5 are obtained. The two groups are less completely separated before treatment i.e. they are more similar (Fig. 4) than after their respective treatment (Fig. 5).

Despite the above findings, 3-D data may be more pertinent in the current debate. Recently, it was reported that no differences in study models arch width was discernible in extraction and non-extraction cases[40], and that smile esthetics are the same in both extraction and non-extraction groups of patients [41]. Indeed, some even suggest the long-term advantages of extraction techniques, reporting significant dental arch improvements in extraction cases with age[42]. More recently, 3-D laser scanning was employed in a preliminary study in which no detrimental 3-D effect on the face was associated with tooth extraction[43]. In a very similar study[44], surface shape changes were detected using a 3-D analysis, highlighting differences in the extraction and non-extraction groups at the start of treatment and end of treatment, similar to the 2-D findings reported in this present study. Currently, some still consider that there is little evidence that orthodontic extractions adversely affect the facial profile[45], but 3-D predictive modeling of the facial features following extraction/non-extraction needs to be undertaken in a future study, employing 3-D geometric morphometric analyses as a robust arbitrator.

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