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Gingival and dentofacial changes in adolescents and adults 2 to 10 years after orthodontic treatment

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Abstract

Background: Information about long-term changes of the shape of the gingival margin is missing.

Aim: To monitor 8 year changes of the gingival contour occurring in adolescents and adults and relate these changes to dentofacial growth.

Subjects and method: Forty adolescents (mean age 16.3), and 14 adults (mean age 29.7) were included in the study with photographs, radiographs and casts taken 2 and 10 years after orthodontic treatment.

The gingival contour of upper central incisors and the midline passing through the contact surface of both teeth were traced digitally using calibrated photographs. Changes were measured on seven standardized lines of the gingival contour. Lower facial height changes and tooth eruption were measured using lateral cephalograms.

Results: Adolescents and adults showed a central mean apical displacement of the gingival margin of 0.51 mm (SD 0.4 mm) and 0.13 mm (SD 0.17 mm), respectively. This displacement decreased by moving away from the centre. The gingival displacement was associated to the individual's lower facial height augmentation, $r = 0.63$ ($p < 0.001$).

Conclusions: Apical displacement of the gingival contour of the upper central incisors takes place during adolescence following a semi-lunar shape. Growth explains parts of these changes.

Key words: gingival changes; gingival shape; lower facial height; tooth eruption; upper central incisors

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With the development of aesthetic dentistry and the evidence of the importance of the gingival level and shape in smile harmony, the concepts of crown length and gingival shape appeared and have been the subject of many publications (Kokich et al. 1984, 1993a, b, Serio & Strassler 1989, Sarver 2004).

In 2004, Sarver stated that the ideal maxillary central incisor proportion is approximately 80% width when compared with the height, and the gingival zenith should be distal to longitudinal axis of maxillary central incisors. Although these guidelines were given for adult patients, it is not known if it is possible to apply these principles when treating growing individuals.

Concerning the position of the gingival margins, Volchansky & Cleaton-Jones (2001) reviewed 11 articles concerning clinical crown height defined as the distance from the most apical curvature of the gingival margin to the incisal edge of the incisors. The authors have shown that there is a statistically significant increase in the clinical crown height of central and lateral incisors with age that slows down with increasing age.

During this period, the vertical position of the upper incisors and the lower facial height are changing (Björk & Skieller 1972). Thus, it is tempting to test if the vertical changes observed in the gingival margin are associated with secondary eruption of these teeth and the increase in the lower anterior facial height.

Although information about the vertical displacement of the gingival margin has been described, it is not clear if it influences the shape of the gingival contour. The ideal shape of this contour for adults has been previously proposed (Olsson et al. 1993, Sarver 2004, Spear

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et al. 2006) but the evolution of this shape with age during adolescence has not been studied.

The aim of this investigation was to conduct a retrospective, longitudinal study to monitor 8-year changes in the form and position of the gingival contour of the upper central incisors occurring in a group of adolescents and in a group of adults using photographic documents. Furthermore, we tested if there is an association between the gingival changes and the vertical dento-facial alterations occurring during this period, as they may be recorded longitudinally using lateral cephalograms.

Material and Methods

Subjects

Fifty-four subjects were included in the study. According to the age of the patients at the first documentation, two groups were defined. The adolescent group comprised 40 subjects (16 males, 24 females) with a mean age of 16.3 years (range: 14.1–18.8). The adult group comprised 14 subjects (four males, 10 females) with a mean age of 29.7 years (range: 20.2–51.2). The first documentation used in our study was performed on average 2 years after the end of the orthodontic treatment and the second documentation was performed 8 years after the first one.

These cases were selected by screening all of the archived cases of our department, searching for patients who finished orthodontic treatment during the period 1984–1996. In order for a case to be included in the study, a documentation with intraoral photographs of the anterior teeth approximately 2 and 10 years after the end of the orthodontic treatment and at least one pair of dental cast, to be used for calibration, taken at one of the two documentation periods, where necessary. The frontal intraoral photographs should have been taken symmetrically from a centric position parallel to the occlusal plane with the central incisors centred on the photograph. No restoration of the upper central incisors during the period between the two registrations should have been carried out or replaced. The oral hygiene should have been good, without visible signs of inflammation.

Sixty-four patients presented the necessary documentation. Ten cases did not meet the inclusion criteria (inadequate quality of photographs, restorations, etc.) and were excluded.

Among the fifty-four subjects included in the study, eight adults (one male, seven females) and 26 adolescents (nine males, 17 females) had lateral cephalogram available both on the first and second documentation period.

Measurements of gingival form and displacement

The slides of the frontal intraoral view of our subjects were digitized using a scanner (Epson 1680pro, SEIKO-EPSON Corp., Tokyo, Japan) with a resolution of 1200 dpi.

On the digital images, the teeth 11 and 21 were traced with a drawing software (FreeHand 8.0, Macromedia Inc., San Francisco, CA, USA) and the line passing through the surface of contact of both teeth parallel to the teeth axis was also traced. The level of the papilla was noted on this line (Fig. 1a and b).

Both drawings from each case were then superimposed adjusting the size of the first drawing relative to the second one, fitting the vertical placement of the drawing on the angles of the incisors. The level of the papilla was then fixed and small modifications for the superimposition of each tooth, when necessary, were carried out individually.

The measurements were done on the image with both drawings superimposed using Viewbox (Version 3.1.1.12, Demetrios Halazonetis, Athens, Greece). The magnification was adjusted by measuring the distance of 11 and 21 using the dental casts and calibrating the image on the computer. The most mesial and the most distal points of teeth 11 and 21 were defined and each tooth was divided into eight equal parts with lines parallel to the principal line using Viewbox (Fig. 1c). The intersections of these lines with the two tracings of the gingival contour and the level of the papillae were then recorded. The gingival displacement on each line was calculated by the computer.

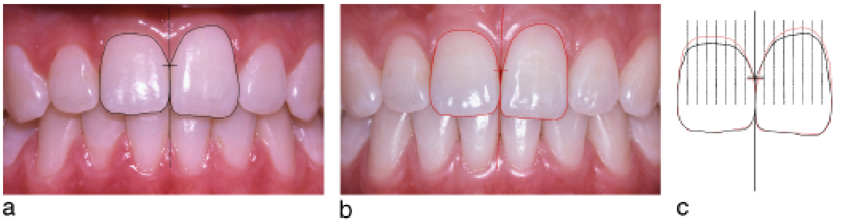
Cephalogram measurements

On the lateral cephalograms (Fig. 2), the lower facial height was calculated by measuring the distance gn–sp'. The distance is–as' from the upper incisal edge to the intersection of the axis of the upper incisor to the palatal plane (sp–pm) and the angle between these two lines were also measured. All measurements were performed with Viewbox on the first and the second lateral cephalograms. The magnification of the radiographs was corrected. The difference of the above-described measures between the two different occasions indicated the lower facial height increment, the amount of tooth eruption and the proclination changes of upper incisors during the follow-up period.

Statistics

All the statistics were conducted using SPSS 13.0 for Windows. Statistical significance <0.05 were considered significant. The average measurements of each site of teeth 11 and 21 were used in the analyses. Thus, changes in all sites were evaluated after two measurements, one on each tooth. This was not the case for the papilla where changes were measured on single measurements.

The changes in the form of the gingiva were tested by evaluating the displacement on the seven points on the gingival contour by using a paired sample *T*-test. The results of the adolescent and the adult group were compared by using an unpaired *T*-test. In order to correlate



a b c

Fig. 1. (a) Initial photograph 2 years after the end of orthodontic treatment with drawings of teeth 11, 21, the central line passing through the surface of contact of both teeth and parallel to the axis of incisors and the level of the papilla in black. (b) Final photograph 8 years after the initial photograph with the same drawings as in (a) but in red. (c) Tracings of initial and final photographs superimposed by fitting the angles of the incisors. The parallel lines to the central axis divide the upper central incisors in eight equal parts.

incisor eruption, lower facial height increment and proclination changes of upper incisors with the gingival displacement, the three gingival values in the centre of the teeth were averaged. The Pearson correlation coefficient was calculated to relate the gingival displacement to tooth eruption, lower facial height increment and proclination changes of upper incisors.

Error of the method

The error of the method was tested using two photographs of 15 subjects taken on the same day on two different occasions. The pictures were traced and superimposed according to the method presented previously and the measurements were analysed using the Dahlberg formula ($Se^2 = \Sigma d^2/2n$) (Houston 1983). The method error ranged from 0.05 to 0.09 mm for the gingival measurements and was 0.11 mm for the level of the papilla.

The method used for the measurements on the lateral cephalograms was evaluated by retracing 30 cephalograms from 4 weeks apart. According to Dahlberg's formula, the error of the method was 0.48 mm for the distance is–as' and 0.36 mm for the distance gn–sp'.

Results

Gingival displacement was mainly centred in the tooth with a mean displacement of 0.51 mm (range −0.26 to 1.76 mm) in the adolescent group and 0.13 mm (range −0.10 to 0.43 mm) in the adult group (Fig. 3). In the adolescent group, the differences in the three central measurements did not show statistical significance. The gingival displacement of the two distal and the two mesial measurements were less pronounced than the central one ($p < 0.05$) (Fig. 4). In the adult group, the two distal measurements were smaller than the central one ($p < 0.05$) (Fig. 5).

No difference was found in the papilla displacement between the two groups. However, the papillae displacement showed a large dispersion probably due to the higher method error obtained for these measurements.

In the adolescent group, a mean incisor eruption along the axis of the tooth of 0.81 mm (SD 1.01 mm) and a mean lower facial height augmentation of 1.36 mm (SD 2.20 mm) was found. In the adult group, the incisor eruption was 0.19 mm (SD 0.54 mm), and the lower facial height augmentation was 0.72 mm (SD 0.76 mm).

An association between the amount of gingival displacement and tooth eruption, $r = 0.45$ ($p = 0.008$) was found. Similarly, an association was found between gingival displacement and lower facial height augmentation, $r = 0.63$ ($p < 0.001$). No correlation between the changes in the proclination of the upper incisors and gingival displacement was found.

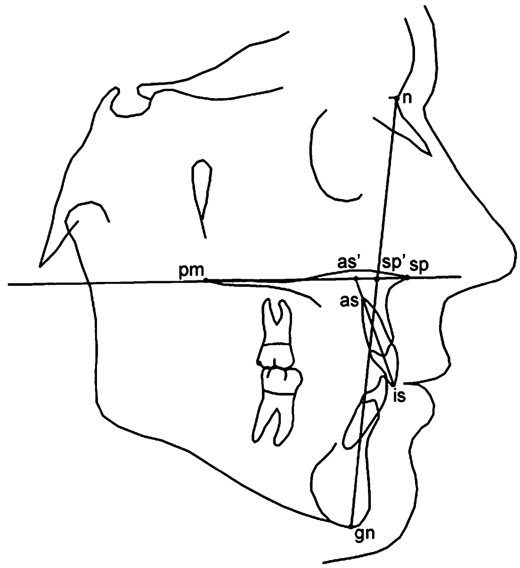


Fig. 2. Skeletal reference points and lines. For definitions, see Solow & Tallgren (1976). n, nasion; sp, anterior nasal spine; pm, posterior nasal spine; gn, gnathion; is, upper incisors incisal edge; as, upper incisors apex; sp', intersection of lines n–gn and sp–pm; as', intersection of lines is–as and sp–pm. The distance is–as' and the distance gn–sp' were calculated on the lateral cephalograms on the first and the second documentation and the difference between these measures indicate tooth eruption and lower facial height augmentation, respectively.

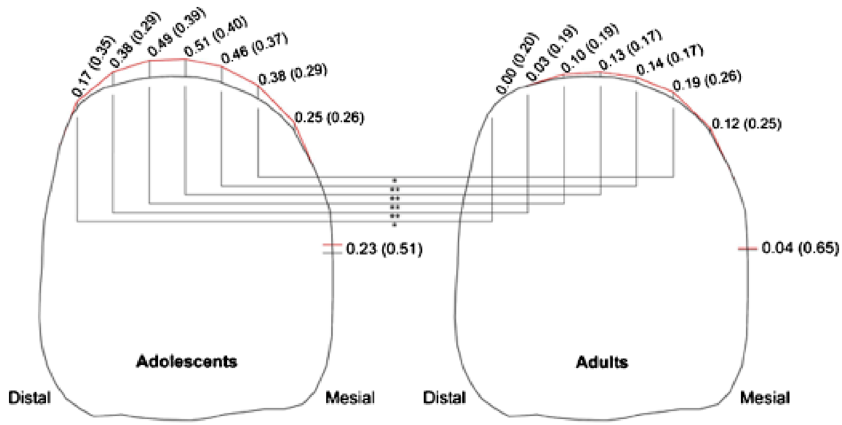


Fig. 3. Schematic representation of the mean recession measured in the adolescent and the adult groups based on both left and right incisors. The outline of a chosen tooth is shown in black and the mean recessions measured are displayed in red. Numbers indicate the mean values obtained for each measurement with the SD in parentheses. Values that are statistically different between the two groups are connected and the asterisks indicate the level of significance ($^*p < 0.05$ and $^{**}p < 0.01$).

Discussion

The present study shows that gingival contour in the adolescent is not stable and a cervical displacement takes place during growth. Our results are in agreement with a 7 years longitudinal study,

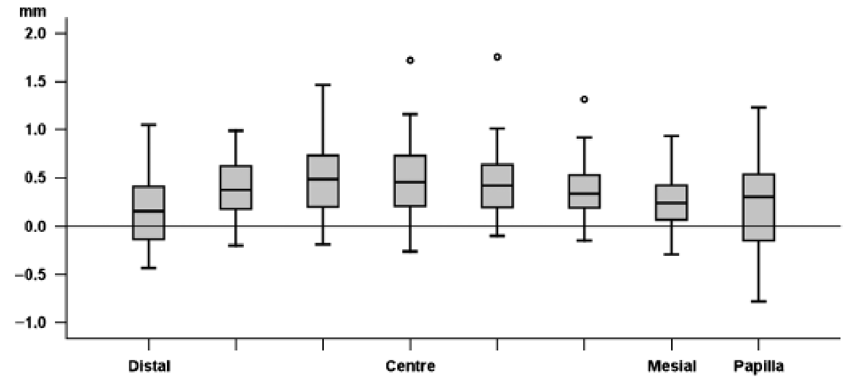


Fig. 4. Box–plot representation of the mean recession measured in the adolescent group based on both left and right incisors of the 40 adolescents observed. Changes in the level of the papilla are also shown. Box identifies middle 50% of data, line across box is median, and whiskers indicate 95% data. Outliers are indicated with small circles.

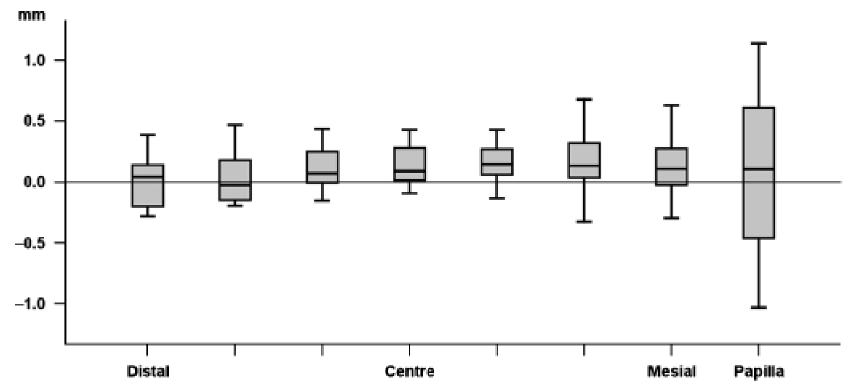


Fig. 5. Box–plot representation of the mean recession measured in the adult group based on both left and right incisors of the 14 adults observed. Changes in the level of the papilla are also shown. Box identifies middle 50% of data, line across box is median, and whiskers indicate 95% data.

where it was found that the crown length of the upper central incisors increases by about 0.85 mm between 11.5 and 18.5 years of age (Morrow et al. 2000). This augmentation is higher than the 0.5 mm we found between 16 and 24 years of age, possibly due to the older age of the subjects in our study.

The cervical gingival displacement resulting in an augmentation of the clinical crown length was found to be related to secondary eruption of the incisors and lower facial height increase.

It has been shown that these vertical dentofacial changes take place in adolescence and adulthood presenting great interindividual variation (Forsberg et al. 1991, Op Heij et al. 2003, Bernard et al. 2004, Christou & Kiliaridis 2008).

It is quite probable that, during adolescence, cervical gingival displacement is not due to attachment loss but rather to a decrease of sulcus depth which is deeper in younger individuals (Smith 1982, Bimstein & Eidelman 1988). This decrease of sulcus depth is more pronounced in younger subjects and slows down with age (Bimstein & Eidelman 1988). Thus, we can assume that during the first phase of secondary tooth eruption, there is an increase in clinical crown length that is followed by a second phase with a vertical increase of the alveolar process. This may lead to the following effects in the gingival region: when it is no more possible to further reduce the depth of the gingival sulcus, an augmentation of the width of the attached gingiva may take place (Ainamo & Talari 1976).

All articles concerning changes in clinical crown height or length considered only one measurement per tooth. These measurements were made with some form of callipers from the most apical curvature of the gingival margin to the incisal edge of the incisors (Volchansky & Cleaton-Jones 1976, Ronnerman 1977, Volchansky et al. 1979, 1981, Larsson & Ronnerman 1981, Ronnerman & Larsson 1982, Abdel-Kader 1986, Bassey 1991, Sterret et al. 1999, Morrow et al. 2000).

Although this concept of measurement is an easy way to obtain gingival displacement, it has some limitations. The enamel loss on the incisal border has not been taken into account, and one measurement per tooth is not enough to describe possible alterations to the form of the gingival border. Besides, the health of the soft tissues was not taken into consideration when measurements were carried out on dental casts. Furthermore, the most apical curvature of the gingival margin could have been displaced along the gingival contour resulting in erroneous findings if there was a change in the axis of measurement.

To overcome these problems, we based our method on photographic documentation of the gingival margin during two periods, approximately 8 years apart. The calibration of the photographic measurements using dental casts decreased the risk of error due to magnification. Nevertheless, the error of method has possibly influenced our results increasing the variation of the measures and decreasing the possibility of detecting statistically significant differences, as is the case for the papilla displacement, between adolescents and adults. Our method also provided the possibility to evaluate alterations in the shape of the whole gingival margin.

However, our retrospective longitudinal study has the drawback that only the upper central incisors could be evaluated accurately. Without standardizing the procedure of image taking, the measurement of gingival displacement of other teeth is not possible due to image deformations being more pronounced on the sides of the photograph. Additionally, the strict inclusion criteria defined in order to reduce possible deformation due to faulty placement of the camera, reduced the number of the subjects included in the study.

Ideally, non-treated cases should have been included in the study but, for ethical reasons, it is impossible to get the necessary radiographic records in the general population. The fact that we have followed-up these individuals starting 2 years after orthodontic treatment, minimized the influence of this intervention on our results. Therefore, we consider that the observations of our sample are most probably similar to those of non-treated patients. This argument is based on previous findings that relapse due to orthodontic treatment takes place the first 2 years after treatment (Kuijpers-Jagtman 2002) and that no statistically significant difference exists between crown height of treated and untreated patients 2 years after the end of treatment (Zachrisson & Alnaes 1973).

Clinical Relevance

In order to improve the aesthetics of the smile, reshaping of the contour of upper front teeth with gingivectomy or flap surgery is often proposed. The results of the present study indicate that, during adolescence, eventual gingival reshaping of anterior teeth for aesthetic reasons should be postponed and re-evaluated in early adulthood. Similarly, tooth replacement with implants should not be performed until adulthood due to the continuous secondary tooth eruption of these teeth. However, vertical changes, though to a lesser extend, were observed among the adult individuals too.

Conclusion

Apical displacement and form changes of the gingival margin of the upper central incisors take place during adolescence. There is an association of gingival displacement to tooth eruption and increase in lower facial height.

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Clinical Relevance

Scientific rationale for the study: The aesthetics of the smile is a decisive factor in orthodontics concerning the correct vertical position of the upper incisors and the ideal exposure of gingiva. However, information about long-term changes of the position and shape of the gingival margin is missing.

Principal findings: Adolescents showed more apical displacement of the gingival margin than adults. These changes can, in part, be explained by tooth eruption and facial vertical growth, which are not completed at the adolescence.

Practical implications: During adolescence, gingival level and tooth position may change. Thus, eventual gingival surgery for aesthetic reasons or implant placement should be postponed and re-evaluated in early adulthood.