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Age-related changes of the dental aesthetic zone at rest and during spontaneous smiling and speech

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SUMMARY The aims of this study were to analyse lip line heights and age effects in an adult male population during spontaneous smiling, speech, and tooth display in the natural rest position and to determine whether lip line height follows a consistent pattern during these different functions. The sample consisted of 122 randomly selected male participants from three age cohorts (20–25 years, 35–40 years, and 50–55 years). Lip line heights were measured with a digital videographic method for smile analysis, which had previously been tested and found reliable. Statistical analysis of the data was carried out using correlation analysis, analysis of variance, and Tukey's *post hoc* tests.

Maxillary lip line heights during spontaneous smiling were generally higher in the premolar area than at the anterior teeth. The aesthetic zone in 75 per cent of the participants included all maxillary teeth up to the first molar. Coherence in lip line heights during spontaneous smiling, speech, and tooth display in the natural rest position was confirmed by significant correlations. In older subjects, maxillary lip line heights decreased significantly in all situations. Lip line heights during spontaneous smiling were reduced by approximately 2 mm. In older participants, the mandibular lip line heights also changed significantly and teeth were displayed less during spontaneous smiling. Mandibular tooth display in the rest position increased significantly. Upper lip length increased significantly by almost 4 mm in older subjects, whereas upper lip elevation did not change significantly.

The significant increasing lip coverage of the maxillary teeth indicates that the effects of age should be included in orthodontic treatment planning.

Introduction

In social interaction, our attention appears mainly directed towards the mouth and eyes of the face of the person speaking (Thompson *et al.*, 2004). As the mouth is the centre of communication in the face, the aesthetic appearance of the oral region during smiling is a conspicuous part of facial attractiveness. The aesthetic (Garber and Salama, 1996) or display (Ackerman and Ackerman, 2002) zone is composed of the size, shape, position and colour of the displayed teeth, the gingival contour, the buccal corridor, and the framing of the lips. The range of the aesthetic zone is defined by the movements of the upper and lower lip during smiling and speech.

Lip position and the amount of tooth and gingival display during smiling and speech are important diagnostic criteria in orthodontics, dentofacial surgery, and aesthetic dentistry. Smiles that entirely display the teeth including some gingiva (2–4 mm) are perceived as the most aesthetic (Kokich *et al.*, 1999; Van der Geld *et al.*, 2007b). Furthermore, a continuous gingival contour should be parallel with the curve of the upper lip (Moskowitz and Nayyar, 1995; Peck and Peck, 1995). The most ideal incisal line of the upper dentition is established in relation to the curve of the lower lip (Sarver, 2001; Ackerman *et al.*, 2004). Therefore, adequate evaluation of lip lines is required for the orthodontic diagnosis, especially in patients with reduced tooth display, unaesthetic gingival contours, exposed posterior gingiva, occlusal cants, asymmetry of the upper lip during smiling, and 'gummy smiles'.

In spite of the relevance of the aesthetic zone in orthodontic treatment planning, relatively little research has been carried out on lip line height and tooth and gingival exposure during spontaneous smiling and speech. A drawback of most studies is that only posed smiles have been measured. It is claimed that such smiling on request has the advantage of reproducibility (Rigsbee *et al.*, 1988; Ackerman *et al.*, 1998), yet it should be questioned whether the posed social smile is the same as a spontaneous smile of joy. The smile in fact is not a singular category of facial behaviour. In psychophysiology, for example a difference is made between emotion elicited spontaneous smiles of joy and voluntary posed smiles (Ekman, 1992). On the basis of structural differences between spontaneous smiling and the posed smile, spontaneous smiling is considered as a focus point for lip line analysis in orthodontic treatment planning (Tarantili *et al.*, 2005). This is in line with the recommendations of oral surgeons (Allen and Bell, 1992) and aesthetic dentists (Moskowitz and Nayyar, 1995). Ackerman *et al.* (2004) proposed that the orthodontist should view the dynamics of anterior tooth display as a continuum delineated by the time points of rest, speech, posed social smile, and a (spontaneous) Duchenne smile. Most of the methods for smile measurement, however, are not designed to measure spontaneous smiles. Consequently, limited data are available to serve as a guideline for lip line heights in spontaneous smiling and speech, particularly for the adult population.

Another important aspect, to consider when evaluating the aesthetic zone, is the effect of age on lip line height. Based on clinical experience, the prosthetic literature demonstrates that with age the lips become less elastic and less mobile. As a result of this, older people are reported to show less of the maxillary and more of the mandibular teeth during smiling (Shillingburg *et al.*, 1997). Dong *et al.* (1999) and Dickens *et al.* (2002) measured changes in the smile as an effect of age. Both studies reported a decrease of maxillary incisor display during smiling. Dong *et al.* (1999) also found a slight increase of mandibular incisor display. In the studies of Vig and Brundo (1978) and Al Wazzan (2004), the maxillary incisor display at rest was found to gradually reduce with an increase in age, while mandibular incisor display increased. It should be noted, however, that most of these results were not statistically tested.

From the starting point that the lip line height is an essential diagnostic criterion in (adult) orthodontics, dentofacial surgery, and aesthetic restorative dentistry, a digital videographic method to measure both spontaneous smiling and speech was developed (Van der Geld *et al.*, 2007a). The specific aims of the present study were firstly to analyse lip line heights and age effects in an adult male population during spontaneous smiling, speech, and in natural rest position with a digital videographic measurement method and secondly to determine if lip line heights followed a consistent pattern during these different functions.

Subjects and methods

The research proposal was approved by the ethical committee of the Academic Centre of Dentistry, Amsterdam. Informed consent was obtained from the subjects according to the guidelines of that institution.

Participants

Of 1069 military males on an air force base, 122 were randomly selected from three age cohorts (20–25 years, 35–40 years, and 50–55 years). Selection criteria were full maxillary and mandibular dental arches up to and including the first molar, Caucasian, no excessive facial disharmonies, and no visible periodontal disease or caries.

Recording and measurement during spontaneous smiling, speech, and at rest

A digital videographic measurement method was used to capture records of a spontaneous smile of joy and during speech. In addition, a record of a spontaneous natural rest position (with the lips slightly parted) and a full dentition record with the aid of cheek retractors were made. The reliability and clinical application of this digital videographic measurement method has been tested previously. The method appeared to be reliable with intraclass coefficients ranging from 0.99 to 0.80 (Van der Geld *et al.*, 2007a).

On the full dentition record, the lengths of the teeth were measured to obtain the actual length of the tooth crowns. On the spontaneous smiling and speech records, the display of teeth and gingiva was measured. In the maxilla and mandible, a central and lateral incisor, a canine, a first and second premolar, and a first molar were measured from the left and right side alternately to exclude influences of facial asymmetry. Digital horizontal lines were used to mark the most incisal point of each tooth (line 1) and the lip edge (line 2, Figure 1). These marking lines were parallel to the inter pupil line. The vertical distance between these lines was measured (see lip position measurement, Figure 1).

Following the concept of Peck and Peck (1995), lip line height was expressed relative to the gingival margin (line 3) and thus is a measurement for both tooth and gingival visibility (Figure 1). Lip line height was calculated as the difference between lip position and tooth length. When the gingival margin was displayed, positive values were assigned both for the maxilla and the mandible. When the teeth remained partly covered, negative values were given. If the upper and lower lip covered both gingival margin and incisal point, lip line height was denoted as not measurable. If a tooth was not visible, lip line height was recorded as missing.

On the record in the natural rest position, the amount of tooth display was measured from the incisal point of each tooth to the edge of the lip. If a tooth was not visible, the tooth display was denoted as zero.

The vertical length of the upper lip was measured between the lower edge of the upper lip and subnasion on the spontaneous smiling record and the record in the natural rest position. The amount of lip elevation during spontaneous smiling was calculated as the percentage difference between upper lip length in the rest position and upper lip length during spontaneous smiling.

Data analysis

Correlation analysis was used to determine if the lip line heights of a subject were coherent during the situations of

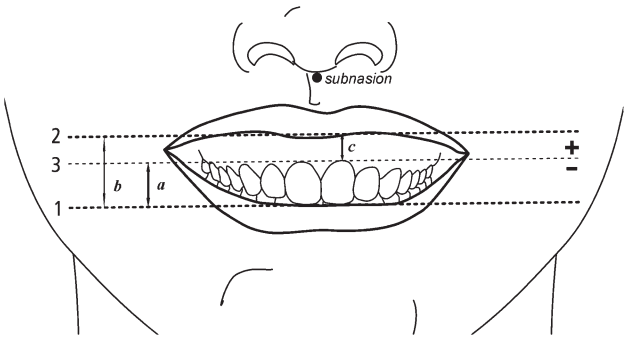

Figure 1 Measurement of lip line height; Line 1: the most incisal point of the central incisor; Line 2: the lip edge on the central incisor; Line 3: cervical margin of the central incisor. Lip line height is lip position minus tooth length. When the gingival margin is displayed, lip line height has positive values. When the teeth are partly covered, lip line height has negative values.

spontaneous smiling, speech, and in the rest position. Following the conventions set by Cohen (1988), correlations of 0.10, 0.30, and 0.50 were considered weak, moderate, and strong, respectively. The significance level $P < 0.05$ was chosen.

Analysis of variance (ANOVA) was used to compare lip line heights for each tooth between the three age cohorts in the situations, spontaneous smiling and speech. ANOVA was performed on each tooth separately as the number of teeth displayed varied between the situations. When the lip line heights were found to differ significantly between the age cohorts, Tukey's *post hoc* tests were performed to identify the cohorts that differed significantly. The same procedure was performed for tooth display in the natural rest position, lip elevation, and upper lip length.

Results

Lip line heights and frequencies of displayed teeth

Lip line heights during spontaneous smiling and speech are shown for the three age groups, for the maxilla and mandible, in Figures 2 and 3, respectively. In Figure 2, the minimum and maximum graphs of lip line heights show a considerable individual variation in some subjects compared with the majority of the sample. In contrast to spontaneous smiling, the maxillary lip line heights during speech were generally lower. The cervical gingival margins were mostly covered by the upper lip.

During spontaneous smiling and speech, the mandibular lip line heights were mostly positioned on the tooth (Figure 3). The cervical gingival margins were thus covered by the lower lip. Contrary to the maxilla, during speech, the mandibular teeth were displayed more than during spontaneous smiling.

The collected data showed that in 75 per cent of the sample, the maxillary first molar was substantially displayed during spontaneous smiling and was part of the aesthetic zone. The mandibular anterior teeth formed part of the aesthetic zone especially during speech in 93 per cent of the participants.

Relationships between lip line heights in different situations

Table 1 shows the correlation analysis used to determine if the lip line heights followed a coherent pattern during spontaneous smiling, speech, and tooth display in the natural rest position. The lip line heights of all maxillary teeth demonstrated a significant and strong to moderate relationship between spontaneous smiling and speech. In the mandible, this applied to the anterior teeth and the first premolar.

Maxillary anterior lip line heights during spontaneous smiling and tooth display in the natural rest position were highly significant and strongly correlated. Maxillary anterior lip line heights during speech and tooth display in the natural rest position also showed a significant and strong to moderate relationship. No correlations between these situations were found for the mandibular teeth.

Age effects on the aesthetic zone

The results of ANOVA, comparing the lip line heights of the three age cohorts during spontaneous smiling, are given in Table 2. The suggestion (Figure 2) that lip line heights gradually decrease with age was confirmed by the significant results for all maxillary teeth. *Post hoc* analysis showed that the significant effects occurred mainly between the 20–25 and 50–55 year cohorts. The mandibular lip line heights also decreased with age; the lateral incisor, the canine, and the first premolar were significantly covered by the lower lip in the older age cohorts.

During speech the effect of decreasing lip line heights with age was significantly manifested in the maxillary anterior region (Table 3). Beside significant effects for all anterior teeth between the 20–25 and 50–55 year cohorts, both incisors also showed significant effects between the 20–25 and 35–40 year cohorts.

In the mandible, no significant age effects on lip line heights during speech were found apart from the central incisor. This single significant effect was possibly caused by a differing mean in the second cohort. As this is not in line with the other results, the findings should be interpreted with caution.

The same as lip line heights during spontaneous smiling and speech, maxillary anterior tooth display in the natural rest position showed a significant decrease with age (Table 4). Significant differences between all age cohorts were found for the maxillary incisors. Opposite to the maxillary decrease of tooth display, mandibular anterior tooth display increased highly significantly in the older subjects.

The upper lip length during spontaneous smiling and in the natural rest position both showed very high significant lengthening with age (Table 5). For both situations, the significant effects occurred between the 20–25 and 35–40 year cohorts and 20–25 and 50–55 year cohorts. For the upper lip elevation during spontaneous smiling, no significant changes were found.

Discussion

Spontaneous smiling and speech have a dynamic nature, which requires a dynamic registration method. However, ear rods are often used for standardization of the head position. This is not a favourable position to elicit a spontaneous smile of joy in patients. Therefore, a less intrusive dynamic registration method based on videographic measurement of spontaneous smiling and speech was developed (Van der Geld *et al.*, 2007a). Since this approach is relatively new in smile analysis, no data were available of adult lip line heights during spontaneous smiling, speech, and tooth display in the natural rest position. This makes a comparison with other studies difficult.

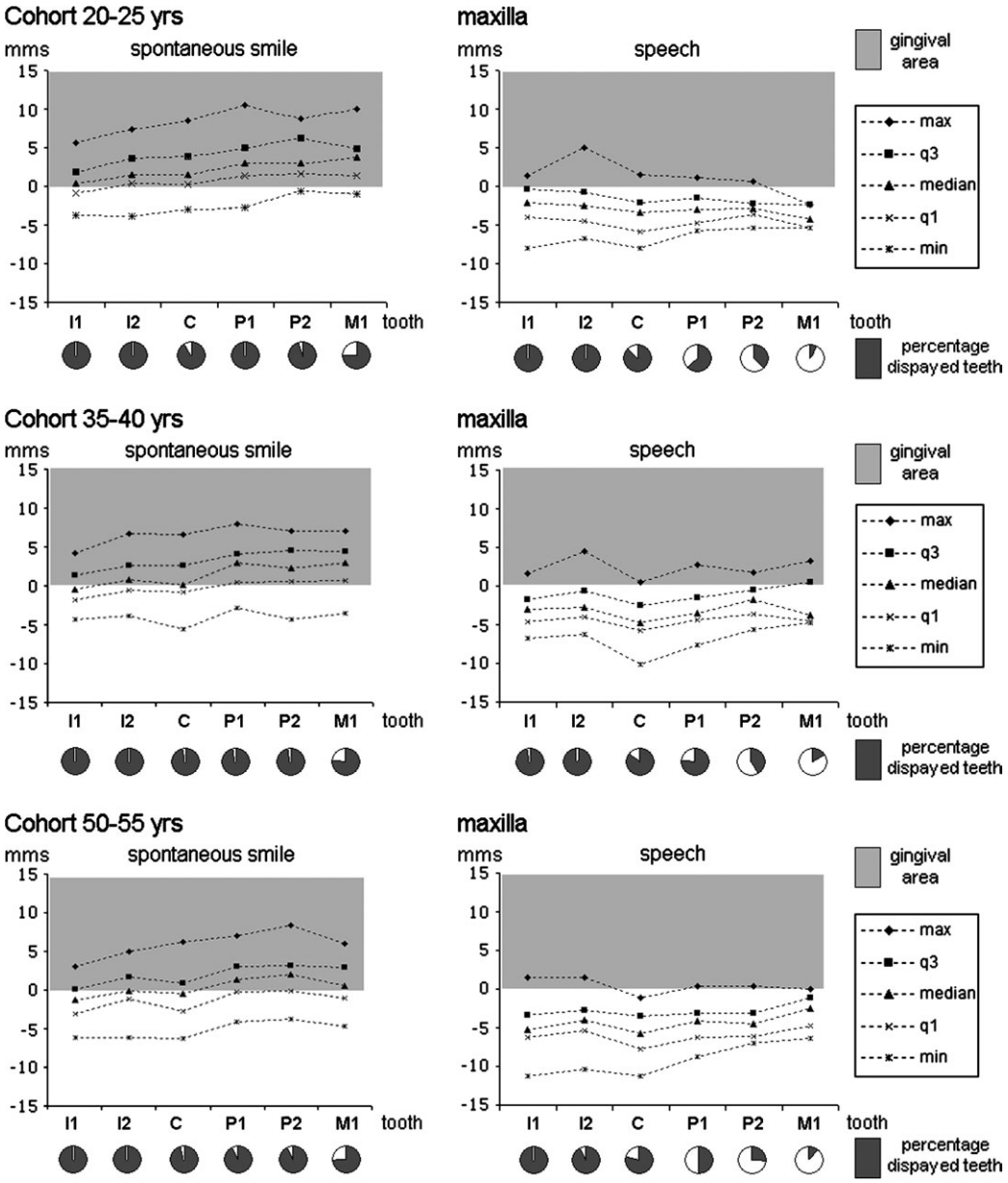

Figure 2 Median, quartiles, and ranges of maxillary lip line heights in millimetres relative to the gingival margin for the upper incisors, canine, premolars, and first molar. The grey shaded areas represent the gingiva. Percentages of (measurable) displayed teeth in the total sample are show in pie charts.

In the present investigation, the sample used was restricted to males. Selection of the sample according to the criteria was accurate because adequate dental documentation was present. Furthermore, a homogeneous sample was needed to exclude factors such as race or gender. This means that the results of this study are valid for Caucasian males only.

As shown in Figure 2, the maxillary lip line heights during spontaneous smiling tended to be generally higher in the premolar area and, for a considerable number of patients, the posterior maxillary region was also part of the aesthetic zone. This finding is in line with a study of posed smiling, in which Kapagiannidis *et al.* (2005) reported that maxillary gingival display was greater for premolars compared with the central incisor and canine. This is important with respect to orthodontic diagnosis and treatment planning. Obviously, during orthodontic treatment more attention is given to incisor lip line heights but at a risk of overexposure of the posterior gingiva. This gingival overexposure is undesirable in the smile and difficult to correct (Mackley, 1993).

Compared with spontaneous smiling, during speech the maxillary teeth were covered more by the upper lip and less displayed. Especially, the maxillary anterior teeth and the first premolar were visible. In the mandible, by contrast, the lower lip moved more towards the gingival margin during speech than during spontaneous smiling (Figure 3). During

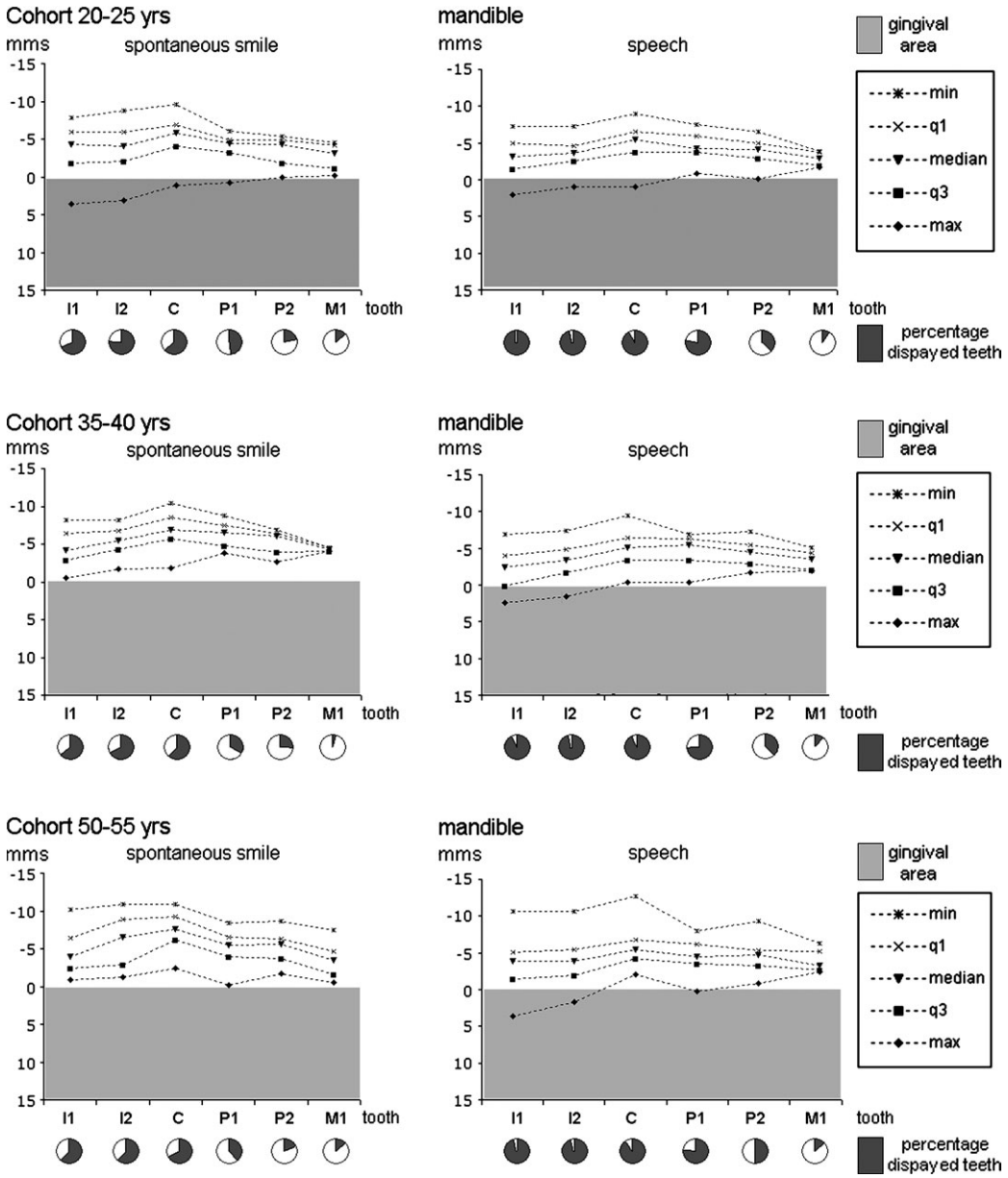

Figure 3 Median, quartiles, and ranges of mandibular lip line heights in millimetres relative to the gingival margin for the lower incisors, canine, premolars, and first molar. The grey shaded areas represent the gingiva. Percentages of (measurable) displayed teeth in the total sample are show in pie charts.

speech a larger number of mandibular teeth (the anterior teeth and the first premolar) were in view and were also more exposed than during smiling.

Ackerman *et al.* (2004) found clinically and statistically significant changes in anterior lip–tooth relationships between posed smiling and speech. In addition, in the present study, the coherence of lip line heights during spontaneous smiling, speech, and tooth display in the natural rest position was determined. This means, e.g., that patients showing higher lip line heights during spontaneous smiling, also showed higher lip line heights during speech as well as a greater amount of tooth display in the natural rest position. The patients' coherence of lip line heights during these situations provides an unambiguous orthodontic strategy as the one functional situation does not require a totally different treatment approach from another.

Limited studies are available that provide data concerning the effect of age on the aesthetic zone. These data are relevant, among others, for predictable long-term aesthetic results of orthodontic therapy. The general assumption, mostly based on clinical experience, that lip line height decreases with age was statistically confirmed for the maxilla in this study. Moreover, the age effect on the perioral tissues is not equal for the maxilla and mandible or for each situation. With age, a decrease of maxillary lip line height and tooth display was found

Table 1 Correlation analysis of coherence in lip line heights of subjects during functional situations. The situations of spontaneous smiling, speech, and tooth display are mutually compared.

	Maxilla						Mandible					
	I1	I2	C	P1	P2	M1	I1	I2	C	P1	P2	M1
Spontaneous smiling speech												
Correlation (*r*)	0.64	0.64	0.68	0.54	0.48	0.57	0.68	0.56	0.62	0.42	0.55	0.07
P value	0.000***	0.000***	0.000***	0.000***	0.002**	0.027*	0.000***	0.000***	0.000***	0.005**	0.053	0.955
Spontaneous smiling at rest												
Correlation (*r*)	0.54	0.56	0.50	—	—	—	0.15	−0.09	0.18	—	—	—
P value	0.000***	0.000***	0.001**	—	—	—	0.404	0.632	0.351	—	—	—
Speech- at rest												
Correlation (*r*)	0.54	0.46	0.35	—	—	—	0.26	0.23	0.30	—	—	—
P value	0.000***	0.000***	0.024*	—	—	—	0.096	0.142	0.072	—	—	—

No data or $N < 10\%$ of the sample.
*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$

Table 2 Analysis of variance and Tukey's *post hoc* test of lip line heights during spontaneous smiling between the three age cohorts.

	Spontaneous smiling											
	Maxilla						Mandible					
	I1	I2	C	P1	P2	M1	I1	I2	C	P1	P2	M1
Cohort 20–25 years												
Mean (mm)	0.4	1.8	1.9	3.1	3.6	3.3	−3.6	−4.0	−5.5	−4.1	−3.5	−2.9
Standard deviation (mm)	2.2	2.5	2.8	2.7	2.6	2.6	2.9	2.8	2.5	1.6	1.9	1.6
Cohort 35–40 years												
Mean (mm)	−0.3	1.1	0.6	2.4	2.5	2.5	−4.0	−5.1	−6.5	−6.0	−5.0	−4.1
Standard deviation (mm)	2.0	2.3	2.6	2.4	2.6	2.5	2.3	1.8	2.2	1.5	1.5	0.4
Cohort 50–55 years												
Mean (mm)	−1.3	0.1	−0.6	1.4	1.6	0.8	−4.7	−6.0	−7.4	−5.1	−5.4	−3.6
Standard deviation (mm)	2.3	2.6	2.7	2.8	2.7	2.8	2.7	3.0	2.3	2.2	2.1	2.3
N	122	122	117	118	116	91	78	82	77	49	28	14
P value	0.003**	0.014*	0.000***	0.026*	0.006**	0.002**	0.288	0.020*	0.014*	0.015*	0.092	0.702
Post hoc Tukey's HSD												
Cohort 1–2	0.303	0.410	0.091	0.572	0.173	0.500		0.255	0.307	0.011*		
Cohort 2–3	0.102	0.209	0.114	0.224	0.294	0.035*		0.427	0.301	0.305		
Cohort 1–3	0.002**	0.010*	0.000***	0.020*	0.004**	0.001**		0.016*	0.010*	0.283		

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

in combination with an increase of upper lip length. For the upper central incisor, lip line heights during spontaneous smiling decreased by 2 mm. Both tooth display and upper lip length in the natural rest position decreased by almost 4 mm.

The age-related increase of upper lip length appeared approximately equal to the reduction of maxillary incisor display in the natural rest position. An interesting finding was that the age-related decrease in lip line height during spontaneous smiling was considerably less than in the natural rest position. It was also interesting to note that in the natural rest position, the age-related effects occurred between all age cohorts. These intercohort effects were less obvious during speech whereas during spontaneous smiling, the age-related effects only occurred between the youngest and oldest age cohorts. At first, the age-related effects appear to diminish in situations where more musculature activity is required. It is presumed that in situations with more perioral musculature activity, as in spontaneous smiling, the initial effects of age on the soft tissues are compensated (Gosain *et al.*, 1996). This is supported by the fact that lip elevation was the same for all ages (Table 5).

In this investigation, a combination of perioral muscle activity and lower lip soft tissue atrophy was considered to play a key role in the opposite mandibular age effects. In the

Table 3 Analysis of variance and Tukey's *post hoc* test of lip line heights during speech between the three age cohorts.

	Speech											
	Maxilla						Mandible					
	I1	I2	C	P1	P2	M1	I1	I2	C	P1	P2	M1
Cohort 20–25 years												
Mean (mm)	−2.3	−2.5	−3.7	−2.9	−2.8	−4.0	−3.0	−3.6	−5.0	−4.7	−3.8	−2.6
Standard deviation (mm)	2.4	2.5	2.4	2.1	1.6	1.5	2.2	1.8	2.2	1.6	1.7	0.9
Cohort 35–40 years												
Mean (mm)	−3.1	−2.4	−4.3	−3.0	−2.0	−2.3	−2.1	−3.2	−4.7	−4.7	−4.2	−3.1
Standard deviation (mm)	2.0	2.4	2.5	2.2	2.1	3.0	2.3	2.3	2.1	1.7	1.5	1.2
Cohort 50–55 years												
Mean (mm)	−4.7	−3.9	−5.8	−4.2	−4.0	−2.9	−3.5	−3.9	−5.6	−4.7	−4.6	−3.8
Standard deviation (mm)	2.4	2.4	2.7	2.6	2.5	2.3	2.6	2.9	2.2	2.0	2.1	1.5
N	121	119	102	76	43	15	118	118	112	92	51	15
P value	0.000***	0.009**	0.004**	0.094	0.055	0.639	0.036*	0.381	0.199	0.995	0.430	0.511
*Post hoc*Tukey's HSD												
Cohort 1–2	0.318	0.993	0.545				0.176					
Cohort 2–3	0.004**	0.016*	0.056				0.032*					
Cohort 1–3	0.000***	0.023*	0.003**				0.723					

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 4 Analysis of variance and Tukey's *post hoc* test of tooth display in the rest position between the three age cohorts.

	Rest position					
	Maxilla			Mandible		
	I1	I2	C	I1	I2	C
Cohort 20–25 years						
Mean (mm)	5.5	4.0	2.1	0.5	0.3	0.3
Standard deviation (mm)	2.2	2.1	1.2	1.0	0.9	1.0
Cohort 35–40 years						
Mean (mm)	3.8	2.7	0.7	0.7	0.7	0.8
Standard deviation (mm)	1.8	1.9	1.4	1.2	1.2	1.3
Cohort 50–55 years						
Mean (mm)	2.0	1.1	0.7	1.5	1.7	1.4
Standard deviation (mm)	1.6	1.5	1.3	1.5	1.6	1.6
N	122	122	122	122	122	122
P value	0.000***	0.000***	0.000***	0.004**	0.000***	0.001***
Post hoc Tukey's HSD						
Cohort 1–2	0.000***	0.006**	0.001**	0.774	0.304	0.223
Cohort 2–3	0.000***	0.000***	0.999	0.032*	0.002**	0.088
Cohort 1–3	0.000***	0.000***	0.001**	0.005**	0.000***	0.001**

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

natural rest position with the least perioral musculature activity, mandibular tooth display increased because of 'sagging' of the lower lip with age. During speech no significant age effects were found. During spontaneous smiling, however, line heights decreased, which means that the lower lip was elevated somewhat higher in the older age group.

The above results show that the effects of age on lip line heights and tooth display for the long-term aesthetic outcome of orthodontic treatment are less relevant for the mandible than for the maxilla. Especially, when intrusion of the upper anterior teeth is indicated in younger patients, caution should be exercised. In patients with short clinical crowns in combination with gingival excess, periodontal surgery is the first choice to improve the harmony between tooth length and displayed cervical gingiva. Furthermore, it should be borne in mind that smiles displaying the teeth including some gingiva

Table 5 Analysis of variance and Tukey's *post hoc* test of upper lip lengths and lip elevation during spontaneous smiling, and upper lip lengths in the rest position between the three age cohorts.

	Rest position	Spontaneous smiling	
	Lip length in mm	Lip length in mm	Lip elevation in %
Cohort 20–25 years			
Mean	20.3	16.0	21.3
Standard deviation	2.7	2.7	7.1
Cohort 35–40 years			
Mean	23.3	18.0	22.2
Standard deviation	2.3	1.9	7.0
Cohort 50–55 years			
Mean	24.0	18.3	23.5
Standard deviation	2.6	2.6	6.9
N	122	122	122
P value	0.000***	0.000***	0.364
Post hoc Tukey's HSD			
Cohort 1–2	0.000***	0.001**	
Cohort 2–3	0.412	0.837	
Cohort 1–3	0.000***	0.000***	

$^{**}P < 0.01$, $^{***}P < 0.001$.

(2–4 mm) are perceived as the most aesthetic (Kokich *et al.*, 1999; Van der Geld *et al.*, 2007b). Even in the 50–55 year group, lip line heights were reduced by approximately 2 mm during spontaneous smiling and almost 4 mm in the natural rest position. In patients with less than 4 mm of gingival display in adolescence or young adulthood, intrusion of maxillary teeth, rather than focussing on a harmonious gingival contour and smile arc, is therefore questionable. Intrusion will inevitably lead to a reduced tooth display at a later age. This is often unacceptable as it is associated with ageing.

Conclusions

1. The upper premolars and first molar are part of the aesthetic zone in most patients.
2. Lip–tooth relationships during spontaneous smiling, speech, and at rest follow a consistent pattern.
3. The significant reduction in maxillary lip line heights with age should be taken into consideration in orthodontic treatment planning.

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References

Ackerman M B, Ackerman J L 2002 Smile analysis and design in the digital era. Journal of Clinical Orthodontics 36: 221–236

Ackerman J L, Ackerman M B, Brensinger C M, Landis J R 1998 A morphometric analysis of the posed smile. Clinical Orthodontics and Research 1: 2–11

Ackerman M B, Brensinger C, Landis J R 2004 An evaluation of dynamic lip-tooth characteristics during speech and smile in adolescents. Angle Orthodontist 74: 43–50

Al Wazzan K A 2004 The visible portion of anterior teeth in rest position. Journal of Contemporary Dental Practice 5: 1–7

Allen E, Bell W 1992. Enhancing facial esthetics through gingival surgery. Bell W H (ed). Modern practice in orthognathic and reconstructive surgery. Saunders, Philadelphia, pp. 235–251

Cohen J 1988 Statistical power analysis for the behavioural sciences. 2nd edn. Lawrence Erlbaum, Hillsdale, New Jersey

Dickens S T, Sarver D M, Profitt W R 2002 Changes in frontal soft tissue dimensions of the lower face by age and gender. World Journal of Orthodontics 3: 313–320

Dong J K, Jin T H, Cho H W, Oh S C 1999 The esthetics of the smile: a review of some recent studies. International Journal of Prosthodontics 12: 9–19

Ekman P 1992 Facial expressions of emotion: an old controversy and new findings. Philosophical transactions of the Royal Society of London. Series B, Biological Sciences 335: 63–69

Garber D A, Salama M A 1996 The aesthetic smile: diagnosis and treatment. Periodontology 2000: (11), 18–28

Gosain A K, Amarante M T, Hyde J S, Yousif N J 1996 A dynamic analysis of changes in the nasolabial fold using magnetic resonance imaging: implications for facial rejuvenation and facial animation surgery. Plastic and Reconstructive Surgery 98: 622–636

Kapagiannidis D, Kontonasaki E, Bikos P, Koidis P 2005 Teeth and gingival display in the premolar area during smiling in relation to gender and age. Journal of Oral Rehabilitation 32: 830–837

Kokich V, Kiyak H, Shapiro P 1999 Comparing the perception of dentists and lay people to altered dental esthetics. Journal of Esthetic Dentistry 11: 311–324

Mackley R J 1993 'Animated' orthodontic treatment planning. Journal of Clinical Orthodontics 27: 361–365

Moskowitz M E, Nayyar A 1995 Determinants of dental esthetics: a rationale for smile analysis and treatment. The Compendium of Continuing Education in Dentistry 16: 1164–1166

Peck S, Peck L 1995 Selected aspects of the art and science of facial esthetics. Seminars in Orthodontics 1: 105–126

Rigsbee III O H, Sperry T P, BeGole E A 1988 The influence of facial animation on smile characteristics. The International Journal of Adult Orthodontics and Orthognathic Surgery 3: 233–239

Sarver D M 2001 The importance of incisor positioning in the esthetic smile: the smile arc. American Journal of Orthodontics and Dentofacial Orthopedics 120: 98–111

Shillingburg Jr H T, Hobo S, Whitset L D 1997 Fundamentals of fixed prosthodontics. 3rd edn. Quintessence, Chicago, pp. 419–420

Tarantili V V, Halazonetis D J, Spyropoulos M N 2005 The spontaneous smile in dynamic motion. American Journal of Orthodontics and Dentofacial Orthopedics 128: 8–15

Thompson L, Malmberg J, Goodell N, Boring R 2004 The distribution of attention across a talker's face. Discourse Processes 38: 145–168

Van der Geld P, Oosterveld P, Van Waas M, Kuijpers-Jagtman A M 2007a Digital videographic measurement of tooth display and lip position in smiling and speech: reliability and clinical application. American Journal of Orthodontics and Dentofacial Orthopedics 131: 301.e1–301.e8

Van der Geld P, Oosterveld P, Van Heck G, Kuijpers-Jagtman A M 2007b Smile attractiveness: self perception and influence on personality. Angle Orthodontist 77: 759–765

Vig R, Brundo G 1978 The kinetics of anterior tooth display. Journal of Prosthetic Dentistry 39: 502–504