Treatment Planning: the Smile

David Birnie and Nigel Harradine

"Every time you smile at someone, it is an action of love, a gift to that person, a beautiful thing."

Mother Teresa
Introduction

The following books are excellent texts on dentofacial aesthetics and provide a sound basis for further reading and thought:

- Proportions of the Aesthetic Face by Powell and Humphries
- Fundamentals of Esthetics by Claude Rufenacht
- Esthetic Orthodontics and Orthognathic Surgery by David Sarver
- Facial and Dental Planning for Orthodontists and Oral Surgeons by William Arnett and Richard McLaughlin
- A Clinical Guide to Anterior Dental Aesthetics by Irfan Ahmad
- Facial Aesthetics: Concepts and Clinical Diagnosis by Farhad Naini
- The Art of the Smile by Rafi Romano

are excellent texts on facial appearance which provide a sound basis for further reading and thought.

Frontal and profile analysis

In descending preference, it is preferred to analyse the smile with the patient present. If that is not possible then photographs are a good substitute; least satisfactory is taking soft tissue measurements from a lateral cephalometric radiograph.

Artistically, the redness of the lips contrasts with the light colour of the teeth to highlight a striking entrance to the oral cavity.

Frontal reference lines

Frontal reference lines for assessing the smile are:

- the interpupillary line
- the midfacial line: a vertical line through soft tissue nasion and the middle of the philtrum

These two lines provided a vertical and horizontal reference system for frontal assessment as shown in Figure 3.1. In addition, the intercommisural line (joining the commisures, the gingival line (a line through the zeniths of the gingival margins) and the occlusal line (through the incisal edges and cusp tips) are helpful as shown in Figure 3.2. These lines are often not parallel to the interpupillary line but should be approximately parallel to each other.

Several methods of profile analysis exist and these gradually become more refined with time. The measurement of soft tissues from a cephalometric radiograph is not always satisfactory and measurement from facial photographs may sometimes be preferable.

One of the most influential
Contributors to the science of facial analysis in recent years has been William Arnett. The facial keys to orthodontic diagnosis and treatment planning were originally described in 1993. (Arnett and Bergman 1993a and 1993b). The use of these keys to perform a soft tissue cephalometric analysis is described by Arnett et al (1999). A synthesis of these concepts, with some updating, is given in Arnett and McLaughlin (2004). In general however, Arnett’s work has not gained great popularity probably because of its complexity.

The integration of cephalometric radiographs and facial photographs gives more scope for useful analyses.

Profile reference line

The vertical reference line is at 90 degrees to the true horizontal defined by the natural head position. Which point locates its anteroposterior position is a matter for debate. The zero meridian passes through soft tissue nasion and Arnett and McLaughlin (2004) suggest the use of a vertical line (True Vertical Line - TVL) through subnasale. It is probable that no single point suits every malocclusion and in cases of maxillary retrusion, Arnett and McLaughlin suggest moving the TVL 1 to 3 mms anteriorly.

The oblique view

Sarver and Ackerman (2003b) suggest that useful information can be obtained from an oblique or three-quarter photograph. In particular, the relationship of the occlusal plane to the curve of the lower lip and the display of the upper maxillary teeth, including the premolars and molars which are not visible from the frontal view. The relationship of the smile arc to the incisal edges and the cusp tips of the upper incisors is uncertain; while the suggested relationship is consonance, in the illustration by Sarver, the lower lip covers half of the second premolar and most of the first molar.

Unattractive features of facial appearance

The following features of facial appearance are generally rated as unattractive:

- severe class 2 or class 3 malocclusions
- little show of vermilion border
- an upper lip that slopes backwards
- a very high or very low smile line
- lack of a well-defined labiomental fold
- an everted lower lip
- extreme bilabial protrusion

The smile

The aesthetic zone is composed of the size, shape, position and colour of the displayed teeth, the gingival contour, the buccal corridors 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, facial expression and speech and the essentials of the smile involve the interaction and relationships between:

- the teeth
- the framework of the lips
- the gingival scaffold (Garber and Salama 1996, Ackerman and Ackerman 2002, van der Geld et al 2008)

Smiling involves:

- the development of prominent nasolabial folds
- flaring of the nostrils
- inferior movement of the nasal tip
Squinting of the eyes is the final part of the smiling process and denotes a natural and spontaneous smile; smiles which do not involve squinting of the eyes appear as joyless.

A very good review of the smile in orthodontics is given by Sarver (2001).

Characteristics of the normal smile
The characteristics of the normal smile are:

- normal incisor show
  - almost all cervico-incisal length of tooth of maxillary anterior teeth displayed
  - only interproximal gingiva displayed
- the upper incisors do not touch the lower lip
- the incisal edges are parallel to the lower lip
- the smile displays at least the first premolars or the first and second premolars
- the upper incisors are approximately the width of the philtrum
- the upper central incisors, lateral incisors and canines are in the golden proportion (1:0.618) (Levin 1978)
- midline coincides with harmonious and balanced smile

Measuring the smile
The smile can be recorded photographically. It is best to do this with close-up photographs of the lower face full face and in profile and with the lips relaxed and smiling as shown in Figures 3.3 to 3.6. While this is recorded statically in the relaxed and smiling lip positions, in the future, video recording and analysis of the smile is likely to give fuller information about the dynamics of the smile.

Akyalcin et al (2013) studied eleven smile characteristics in patients treated to ABO standards and compared these to a subjective overall rating of smile attractiveness carried out by orthodontists, general dentists and the parents of patients. The authors found that smile attractiveness could not be fully explained using the eleven smile characteristics measured but that a harmonious smile arc relationship and less gingival display during smiling were significantly associated with smile attractiveness in the treated patients.

Videographic smile recording
Van der Geld et al (2007) have described a reliable way in which to capture the spontaneous smile using a video camera. Sarver and Ackerman (2003a and 2003b) have advanced the concept of videographic recording of smile dynamics and speech. Given the dynamic nature of facial expression, this is a logical way to progress. At the moment however, while it is technically possible to record this data, analysing it is more difficult and less certain. Sarver records smile and speech form both frontal and oblique aspects for about 5 seconds each which yields about 2 x 4 Mb or 2 x
150 frames of video data. The video clip is then reviewed and the frame that best represents the patient's social smile is selected for static analysis.

The spontaneous smile usually produces greater incisor and gingival display than the posed smile.

Ackerman et al (1998) have described a reliable and repeatable method of recording the unstrained posed smile. The smile may be unposed, a result of happiness or emotion, or posed, which indicates a greeting, appeasement or self-assurance. The posed smile can be subdivided into strained – forced and unnatural – or unstrained which looks natural and can be sustained. Both Hulsey (1970) and Rigsbee et al (1988) have concluded that both the unstrained and the strained smile are reproducible. Frush and Fisher (1958) discussed the relationship between the curvature of the incisal edges of the upper anterior teeth and the curvature of the upper border of the lower lip. They also defined the buccal corridor as the space developed when a patient smiles, between the buccal surfaces of the posterior teeth and the commissure of the lips. The method of smile measurement described by Ackerman et al (1998) depends on drawing vertical and horizontal lines on a photograph of an unstrained posed smile. The vertical lines correspond to the commissures of the lips, the distal embrasure of the upper canines (thus establishing a second method of defining the buccal corridors originally described by Hulsey (1970) and the dental midline. The horizontal lines correspond to the upper border of the upper lip, the lower border of the upper lip, the incisal edge of the right central incisor, the upper border of the lower lip and the lower border of the lower lip. The following measurements can then be obtained:

- maximum upper incisor exposure
- upper lip drape
- lower lip to upper incisor
- interlabial gap at rest and smiling
- commissure (smile) width
- **smile index**

The smile index was described by Ackerman et al (1998). It is defined as follows:

\[
\text{Smile index} = \frac{\text{Intercommisure width}}{\text{Interlabial gap on smiling}}
\]

The lower the smile index, the less youthful the smile appears (because there is relatively less tooth display).

- **frontal intercanine width**
  the intercanine width as measured from a full-face photograph

- **right and left buccal corridor**
  the buccal corridor is measured from the mesial line angle of the maxillary first premolars to the inner aspect of the commissure

- **buccal corridor ratio**

Over-elaborate quantitative measurement of the smile is unnecessary for clinical purposes but may be necessary for research. Ackerman's method puts together several different type of measurement so it is perhaps helpful to break these down.

**Incisor display**

With the lips at rest, Ahmad 2005b has described four factors that define incisor display and remembered by the acronym LARS:

- upper Lip length
- Age
- Race
- Sex
Upper lip length

Rigsbee et al (1988) looked at the influence of animation on smile characteristics. They determined that women showed greater facial animation than men and that during smiling, the nasal width increased by 14%, there was 20% shortening of the upper lip, and the mouth width increased to 130% of the original. The upper lip length was greater for males than females by 2.6 mm at rest and 3.2 mm when smiling. On average, for the total sample, upper incisor exposure was 9.7 mm and the interlabial gap was 11.8 mm. Orthodontically treated patients had more upper incisor exposure on smiling and also a greater interlabial gap.

Ahmad 2005b provides a table of lip lengths but does not differentiate between males and females nor does it give the age to which the measurements refer; a modified version of this table is given in Table 3.1 and Ahmad argues that the amount of incisor exposure is predominantly a muscle determined position.

An interesting paper on upper lip changes and gingival exposure on smiling is given by Miron et al (2012). This study was done on males and females with a mean age of approximately 30 years (range 20-40 years). Smile pattern was classified according to the three categories defined by Tjan et al relating to the anterior maxillary tooth crown exposure at maximum smile: “low smile” displaying less than 75% of the clinical crown height of the maxillary anterior teeth, “average smile” revealing 75% to 100% of the maxillary anterior crown height, and “high smile” exposing the whole anterior maxillary crown height and a band of contiguous maxillary gingiva.

Total lip elevation length was defined as smiling maxillary central incisor display + gum exposure in smile – resting maxillary central incisor display to measure the vertical exposure capacity of the lip. This variable is complementary to the smiling/resting external upper lip length ratio variable in representing the upper lip’s vertical contraction during smiling. Note that the authors did not calculate this measurement when there was a negative upper incisor display. The paper also refers to a neat ruler for measuring lip lengths produced by GDIT. The differences in measurement between males and females are given in Table 3.2. The authors also related the sex and measurements of lip length and incisor exposure to patients with high, normal and low smiles and this data is given in Table 3.3. The paper showed that over 50% of women had high smiles compared with only about 25% of men. The paper concluded that patients with high smiles had:

- short upper lips
- low smiling/resting upper lip length ratio indicating greater upper lip shortening on smiling
- low attachment of the upper labial vestibule
- prominent upper lip vermilion

Van der Geld et al (2011) has proposed the following useful semi-quantitative categorisation of the smile line:

- < 75% of incisor crown height showing is a low smile line
- between 75% and 100% of the incisor crown height showing is a normal smile height
• showing the total incisor crown length of a tooth and a continuous band of gingiva (minimum, 1 mm) is classified as a high smile line
• a lip line height that showed more than 4 mm of gingiva is classified as a gummy smile line

Age
Age is the second LARS factor. As people age, the amount of maxillary incisor show decreases and the amount on mandibular incisor show increases. Physiological, pathological and psychological aging all contribute to reduced tonicity of the orofacial muscles and laxity of the tegumental relief in the lower part of the face result in the formation of nasolabial, labial and mental grooves and ridges.

The effect of age is shown in Figures 3.8 and 3.9. Upper incisor exposure becomes less and lower incisor exposure becomes greater (Choi et al 1995, quoted in Dong et al 1999).

Chetan et al (2013) studied smile dynamics in four different age groups (15–19 years, 20–29 years, 30–39 years and 40–50 years). They measured upper lip length, lip thickness, outer commissural width and commissural width from still video frames with the patient’s lips at rest and smiling. The authors concluded that:

• the smile changes with increasing age and those changes differ between males and females
• as age increases, the loss of resting muscle tone and increased flaccidity and redundancy contribute to a lowering of the smile height
• males have more vertical movements whereas females have more horizontal movements during smiling

This paper has a number of flaws, not least that none of the original data is provided, but the idea that we should study smile dynamics with age is an eminently sensible one.

Race
Ahmad 2005b suggests that there is a decreasing amount of maxillary incisor show and an increasing amount of mandibular incisor show from Caucasians, Asians and Blacks. We have not found any studies to corroborate this
although the hypothesis that there are racial differences between lip lengths seems reasonable.

Sex
The differences in lip length and incisor show between sexes has already been discussed.

Naini (2011) has the following additional factors which may influence the relationship between the upper lip and the maxillary incisor.

- the vertical position of the anterior maxilla and labial segment teeth
- the anteroposterior position of the maxilla and the upper incisor teeth. Maxillary deficiency will result in less upper incisor show and forward positioning of the maxilla will result in increased upper incisor show
- the inclination of the upper incisor teeth. Retroclination of proclined teeth increase incisor show while proclination of normally inclined teeth decreases incisor show
- maxillary incisor crown height either because of
  - short or long crowns
  - incisal edge wear
  - the gingival margins on the labial surface of the upper incisors

Tjan et al (1984) and Dong et al (1999) have useful summaries of some of the aesthetic factors relating to the smile as described below.

Upper lip position (smile line)
The three categories of upper lip position on smiling are given in descending order of aesthetic rank.

The term gingival smile line (GSL) refers to the show of a contiguous band of gingivae. Gingival smile lines are often thought to be unattractive; however, a small band of contiguous gingivae (up to 25% of incisor height) is acceptable. Females, on average, show 1 mm of gingival smile line and males show –1 mm. In addition, round faces tolerate gingival smile lines better than long thin faces. Normally, both patients with gingival smile lines and those without have normal upper lip lengths.

The gingival margin of the upper canine should be at the height of the upper lip when smiling.

Sarver and Ackerman (2003a) suggests a more detailed analysis of the morphology of the upper lip and its relationship to the upper incisors. These include:

- **height of the philtrum**
  the height of the philtrum is measured from subnasale to the lowest point of the upper lip midway between the philtral columns. The relative height of the philtrum in relation to the height of the commissures is the important measurement rather than the absolute height of the philtrum. In adolescents, the height of the philtrum is usually shorter than the commissure height but this differential decreases as the face matures
- **height of the commissures**
  the height of the commissures is measured perpendicular to a horizontal line through subnasale
- **interlabial gap at rest and when smiling**
  'at rest' value is only measured when lip incompetence is present
  - maxillary incisor exposure at rest and smiling
  - maxillary central incisor crown height
  - gingival display
  - smile arc
Van der Geld et al (2008) have described how maxillary lip line heights during spontaneous smiling tended to be higher in the premolar area and, for a considerable number of patients, the posterior maxillary region was also part of the aesthetic zone. During orthodontic treatment however, more attention is given to incisor lip line heights but with a risk of overexposure of the posterior gingiva. During speech, less maxillary incisor and gingiva were displayed compared with spontaneous smiling but more lower incisor was displayed. In van der Geld’s study, the coherence of lip line heights during spontaneous smiling, speech, and tooth display in the natural rest position was determined eg: 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. This means that these problems can be addressed by a single orthodontic strategy. For the upper central incisor, lip line heights during spontaneous smiling decreased by 2 mm. Maxillary tooth display decreased by and upper lip length increased by almost 4 mm in the natural rest position. Where considerable perioral muscular activity is required such as in spontaneous smiling, additional muscle activity slows the age-effects. In the 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 but during spontaneous smiling, lip line heights decreased, which means that the lower lip was elevated somewhat higher in the older age group. All in all, an excellent and interesting paper which adds considerably to our knowledge about age related changes in the smile. Desai et al (2009) carried out a cross-sectional study on changes in the dynamic smile; they found that maxillary incisor display decreased with age but that the smile index increased significantly. No subject in the 50 and over age group had a high smile, and no subject in the 15- to 19 year group had a low smile. All dynamic measurements indicated a pattern of decreasing change from rest to smile, especially evident after ages 30 to 39 years. As a person ages, the smile gets narrower vertically and wider transversely and the ability of the perioral muscles to create a smile decreases with increasing age.

<table>
<thead>
<tr>
<th>Aesthetic Rank</th>
<th>Upper lip position</th>
<th>% Occurrence</th>
<th>Description of incisor and gingival show</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Average</td>
<td>56%</td>
<td>75% to 100% of maxillary anterior teeth and interproximal gingivae only</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>29%</td>
<td>maxillary anterior teeth and a contiguous band of gingivae</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>15%</td>
<td>less than 75% of anterior teeth</td>
</tr>
</tbody>
</table>

Table 3.4: Table of upper lip position on smiling in descending order of aesthetic rank

<table>
<thead>
<tr>
<th>Aesthetic Rank</th>
<th>Upper lip curvature</th>
<th>% Occurrence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upward</td>
<td>12%</td>
<td>the corner of the mouth is higher than the centre of the lower border of the upper lip</td>
</tr>
<tr>
<td>2</td>
<td>Straight</td>
<td>45%</td>
<td>the corner of the mouth is level with the centre of the lower border of the upper lip</td>
</tr>
<tr>
<td>3</td>
<td>Downward</td>
<td>43%</td>
<td>the corner of the mouth is lower than the centre of the lower border of the upper lip</td>
</tr>
</tbody>
</table>

Table 3.5: Table of upper lip curvature on smiling in descending order of aesthetic rank

<table>
<thead>
<tr>
<th>Aesthetic Rank</th>
<th>Upper lip parallelism</th>
<th>% Occurrence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Parallel</td>
<td>60%</td>
<td>incisal edges of upper anterior teeth are parallel to the upper border of the lower lip</td>
</tr>
<tr>
<td>2</td>
<td>Straight</td>
<td>35%</td>
<td>the incisal edges of the upper anterior teeth are horizontal</td>
</tr>
<tr>
<td>3</td>
<td>Reverse</td>
<td>5%</td>
<td>the incisal edges of the upper anterior teeth are curved in reverse to the upper border of the lower lip</td>
</tr>
</tbody>
</table>

Table 3.6: Table of parallelism of upper incisor curve to lower lip on smiling in descending order of aesthetic rank

<table>
<thead>
<tr>
<th>Aesthetic Rank</th>
<th>Upper incisor contact</th>
<th>% Occurrence</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Not touching</td>
<td>54%</td>
<td>the incisal edges of the upper teeth do not touch the lower lip</td>
</tr>
<tr>
<td>2</td>
<td>Touching</td>
<td>36%</td>
<td>the incisal edges of the upper teeth just touch the lower lip</td>
</tr>
<tr>
<td>3</td>
<td>Slightly covered</td>
<td>10%</td>
<td>the incisal edges of the upper teeth are slightly covered by the lower lip</td>
</tr>
</tbody>
</table>

Table 3.7: Table of relationship between upper incisors and lower lip on smiling in descending order of aesthetic rank
Upper lip curvature
The three categories of upper lip curvature on smiling are given in descending order of aesthetic rank.

Parallelism of upper incisor curve with lower lip (smile arc)
David Sarver (2001) has devoted a whole paper to this topic. The three categories of parallelism of upper incisor curve to lower lip are given in descending order of aesthetic rank. The smile arc is sometimes referred to as the smile line.

It can be seen that the parallel or consonant smile is both the most attractive and the most common. Ackerman (1998) compared a group of treated and untreated patients; 40% of the treated patients showed a change in smile arc and 32% showed flattening of the smile. In the untreated group, 13% had a change in smile arc and 5% exhibited flattening. It should be noted that Janson et al (2011) in their thoughtful systematic review of research into factors influencing smile attractiveness concluded that no research on actual subjects as yet supports the view that smile arc, as an individual factor, influences smile attractiveness.

The term smile arc is defined as the curvature formed by the incisal edges of anterosuperior teeth. To be considered an aesthetic and youthful smile, this curvature must be consonant or harmonious to the superior margin of the lower lip. Women’s smiles feature a sharper curvature, whilst in men the curvature appears more flat. In individuals with brachycephalic facial pattern, the smile arc is flatter than in mesocephalic and dolichocephalic individuals.

Maganzini et al (2013) measured none smile criteria using a standardised smile analysis to assess improvement during orthodontic treatment of high (>20) and low (<20) ABO Discrepancy Index cases. The nine criteria were:

- incisor exposure
- (gingival) smile line
- lower lip to maxillary incisor
- interlabial gap
- smile width (the distance between the outer commissures of the lips)
- smile index (the interlabial gap divided by the smile width)
- right buccal corridor
- left buccal corridor
- consonance of smile arc

The authors found that smile aesthetics were equally improved by orthodontic treatment in both groups. Five smile characteristics were improved as a result of treatment and these were: incisor exposure, smile line, smile width, decreased buccal corridor width and improved smile consonance.

Consonance of the smile arc is not quantified; while reverse or flat smile arcs are unattractive, there is no agreement on how much curvature of the smile arc is required to give an attractive smile. An educated guess suggests that a smile arc with a chord depth of 50%-70% of the chord depth of the curvature of the lower lip is satisfactory.

Kaya et al (2013) have suggested that flat smile arcs are preferred by raters in patients with insufficient gingival display and more consonant smile arcs are preferred in patients with excessive gingival display. This finding is interesting and requires further corroboration.
Relationship between upper incisors and lower lip
The three categories of relationship between upper incisors and lower lip are given in descending order of aesthetic rank in Table 3.7.

The number of teeth displayed on smiling
The number of teeth displayed on smiling has been described by Tjan et al (1984) and Yoon et al (1992). The results are shown in Figure 3.10. In aesthetic rank, smiles which show first molar to first molar are judged the most attractive and these are closely followed by smiles which show second premolar to second premolar and second molar to second molar. Smiles which show only the six anterior teeth are very uncommon (< 7% in both samples).

Kim and Giannelly (2003) compared the aesthetics of smiles in extraction and non-extraction cases without arch expansion and could find no difference between the two groups.

According to Rufenacht, patients with thin lips should have less dominant teeth than patients with thicker lips. While when looking at the face horizontal and vertical symmetry are important, radiating symmetry is more important when looking at the dentofacial area ie: on either side of the upper dental midline, teeth appear as mirror images of each other.

Buccal corridors
The two ways of measuring buccal corridor width merit some discussion. The method described by Hulsey (1970) is described as:

\[ \text{Buccal corridor ratio} = \frac{\text{Frontal intercanine width}}{\text{Commisure width}} \]

whereas that of Frush and Fisher (1958) is

\[ \text{Buccal corridor ratio} = \frac{\text{Inner commisure width} - \text{visible maxillary dentition}}{\text{Inner commisure width}} \times 100 \]

The Frush and Fisher method is strongly preferred as a more valid measure of buccal corridor ratio. Moore et al (2005) described a measure of smile fullness as:

\[ \text{Smile fullness} = \frac{\text{Visible maxillary dentition}}{\text{Inner commisure width}} \times 100 \]

and smile breadth as:

\[ \text{Smile breadth} = \frac{\text{Outer commisure width}}{\text{Width of face at level of commissures}} \times 100 \]

The study of Moore et al (2005) characterised smile fullness by buccal corridor ratio as shown in Table 3.8.

<table>
<thead>
<tr>
<th>Smile category</th>
<th>Percentage BCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>narrow</td>
<td>28%</td>
</tr>
<tr>
<td>medium-narrow</td>
<td>22%</td>
</tr>
<tr>
<td>medium</td>
<td>15%</td>
</tr>
<tr>
<td>medium-broad</td>
<td>10%</td>
</tr>
<tr>
<td>broad</td>
<td>2%</td>
</tr>
</tbody>
</table>

Table 3.8: Smile fullness categorised by percentage buccal corridor ratio

Digitally altered photographs of smiling faces with different categories of smile fullness were judged by a panel of lay members who concluded that having minimal buccal corridors (broad smile) was a preferred aesthetic feature in men and women.

However, this contrasts with the study of Roden-Johnson et al (2005) who suggested that lay people had no preference between treated (narrow-tapered and normal-broad) archforms and untreated controls;
furthermore, they argued that buccal corridor width did not affect smile rating by orthodontists, dentists or lay people.

Details of study design, such as the extent of the digital alteration or the definition of buccal corridor, are probably important in these investigations. We feel that the measurement and design used by Moore is the more sound.

Parekh et al (2006) investigated the attractiveness of smile arc and buccal corridor width and found that excessive buccal corridors and smile arcs were rated less attractive by both orthodontists and lay persons. In addition, flat smile arcs decreased attractiveness regardless of the buccal corridor width.

Martin et al (2007) determined that both lay people and orthodontists prefer smiles with smaller buccal corridors. Orthodontists were more discriminating than lay people and detected smaller differences between smiles than lay people as supported by Kokich et al (1999). Martin et al suggest that studies which have found no difference in preference between large and small buccal corridors have used intercanine width rather than visible maxillary dentition for calculating buccal corridor ratios.

Yang et al (2008) carried out an interesting study to determine which hard and soft tissue factors were related to buccal corridor area ratio (BCAR).

\[
BCAR = \frac{\text{Buccal corridor area}}{\text{Smile area}} \times 100
\]

This study is to be recommended for its innovative but very accessible method of measuring the buccal corridor spaces and found no effect of extractions on buccal corridor spaces. Importantly and understandably, the cases were not randomised for extraction or matched in any way. Long faces tended to have less buccal corridor area and buccal corridor area was negatively associated with increased soft tissue height (subnasale to soft tissue menton), the amount of upper incisor exposure and the sum of tooth widths from upper left to upper right first molar. There was no difference in buccal corridor area between extraction and non-extraction groups. Note that this study used upper intercanine width rather than the visible dentition to determine where the buccal corridor started.

The study by McNamara et al (2008), found no relationship between buccal corridor spaces or upper incisor exposure and smile aesthetics as rated by both lay persons and orthodontists. Here again, we have to be cautious about that finding because buccal corridor spaces were measured using the Smilemesh software program which defines buccal corridor spaces as the distance between the canines and the outer commissure. We would generally prefer to define buccal corridor spaces as the distance from the widest tooth to the inner commissure.

Ioi et al (2009) confirmed, using a group of orthodontists and a group of dental students, that both groups preferred broader smiles (buccal corridor ratio < 10%) and that above 10%, the difference in perception became clinically significant. It is worth looking at the illustrations in this paper which also used digital alteration of BCS. They found that lay judges preferred smaller BCS. However, in our opinion, their digital manipulation produced a highly unrealistic imitation of a naturally occurring narrow arch, which gave an appearance of extraction of all buccal teeth. A further point in this paper is that the judges were all orthodontists and dental students. Genuinely lay judges are much more appropriate in such a study.

Lay judges were used in a study by McLeod et al (2011) and interestingly, lay opinion was fussier in Canada than in the USA about acceptable limits for BCS and for gum exposure on smiling. The illustrations in that paper clearly show the ideal and acceptable ranges for these and other smile features. The authors point out that the narrow focus on the smile area and the specific use of a ‘slider’ to mark the chosen illustrations may well have made the lay judges give a more stringent view of acceptability that in real life.

Springer et al (2011) used a novel method involving digital manipulation of smile components by lay people using a slider. One finding was the poor reliability of the results for measurement of buccal corridor spaces. It is interesting to note that Janson et al (2011) in their review of the factors influencing smile attractiveness were
critical of many of the studies into buccal corridors on the grounds that many had an unrealistic representation of the smile and/or an insufficient number of lay judges. They concluded that there is as yet no convincing evidence that buccal corridors affect smile attractiveness.

**Key Point:** Interpretation of research requires scrutiny of the actual dimension which was measured and the specific experimental setup.

Ahmad 2005b suggests that the anterior and lateral negative spaces act as a border to the dental elements with the lips providing the picture border. Anterior negative space is present in speech and laughter and bilateral negative spaces should be present when a patient has a relaxed smile.

Medium broad smiles with a buccal corridor ratio of around 10% and a consonant smile arc seem to be the most attractive.

**Extractions and smile width**

Interestingly, the clever study by Spyropoulos et al (2001) that used computerised modification of photographs concluded that factors other than profile outline may be more important in facial aesthetics for lay people and it is orthodontists who pay particular attention to the profile. Orthodontic treatment involving extractions has been accused in recent years of causing larger dark intraoral spaces lateral to the buccal segments. However, the study by Johnson and Smith (1995) found no evidence of this and also no evidence that extractions produced less attractive smiles in the opinions of lay judges.

Two more recent studies by Ganelly have looked at the relationship between extractions and width of dentition. In the first, Ganelly 2003a, he compared a non-extraction group with an extraction of four first premolars group. The principal finding was that post-treatment, canine, premolar and widest molar widths were essentially the same in the two groups. The second similar study (Ganelly 2003b) is more interesting. The first point of note is that he added a measurement at constant arch depth from the upper central incisors and this depth corresponded to the average depth of the molar-premolar contact in a group of non-extraction patients. This is a sound idea, since measurement at a constant arch depth overcomes the problem that non-extraction may well involve distal movement and therefore molar expansion whilst conversely there is frequently molar constriction in extraction case just because the molars move mesially into a narrower part of the arch. The results for this measurement at constant arch depth showed that the extraction group was slightly wider after treatment than were the non-extraction group. This is a good measurement for future studies. The second part of the study was similar to that by Johnson and Smith. Fifty lay judges were asked to rate close up photos of 12 extraction and 12 non-extraction smiles. There were no differences in the aesthetic scores between the groups. Interestingly, the lay judges again seemed unaware of ‘dark buccal corridors’ as an aesthetic factor in smiles, since only one of them mentioned it at all. Also there was no difference in the number of teeth displayed in the two groups whilst smiling.

**Key Point:** When comparing extraction and non-extraction cases, measurement of arch width at a constant arch depth is more informative than measurement of changes in width of a specific tooth.

These two studies are similar in many respects to many studies comparing profiles in extraction and non-extraction groups. They are useful in that they look at (and indeed refute) the idea that extraction results in a narrow arch at the dental smile width, but this leaves unanswered what would result if the same cases were treated with the two regimens – especially if the space requirements were substantial. The Ganelly studies naturally involved cases where clinicians had picked horses for courses when choosing to treat extraction or non-extraction. The cases were not matched. One of the conclusions in a thoughtful systematic review by Janson et al (2011) discussed below is that the studies by Ganelly are good research which does indeed support the view that premolar extractions per se do not have a detrimental effect on smile aesthetics.
Increased gingival display

Some of the concepts relating to increased gingival display (gummy smile) have already been discussed. Diagnosis and treatment planning involves assessing the following factors:

- the relative vertical relationship between the posterior and anterior occlusal plane
- the amount of gingival display
- the crown lengths of the maxillary incisors
- the facial type
- the likely effect of future facial growth and aging

It is probable that orthodontists and oral surgeons have been too quick to treat mild amounts of gingival display – it is frequently much less unattractive than previously thought and of course naturally decreases with age.

Where the anterior occlusal plane has increased vertically (over-erupted) relative to the posterior occlusal plane, then orthodontic intrusion of the maxillary incisors will lift the gingival margins of the anterior teeth as intrusion occurs thus improving the amount of gingival display. If in the same situation, the crowns of the maxillary incisors are short due to tooth surface loss or trauma, then intrude the anterior teeth to get the correct gingival margin relationships and have the teeth restored as appropriate (Kokich 1993b).

Deguchi et al (2008) compared the effects of J-hook headgear and miniscrews on incisor intrusion; the force to intrude the incisors was generated by ligatures, rather than an elastic force (elastomeric or spring), to give a discontinuous force. There were significantly greater reductions in overbite, maxillary incisor to palatal plane, and maxillary incisor to upper lip in the implant group than in the J-hook headgear group; mean intrusion for the miniscrew group was 3.6 mm and 1.1 mm for the J-hook headgear group. The miniscrews produced a more force in the vertical force vector and smaller vector, than the J-hook headgear group. Furthermore, significantly less root resorption was observed in the implant group compared with the J-hook headgear group; this was attributed to a long rest/healing period due to the discontinuous force produced by the ligatures.

Treatment of increased gingival display

Garber and Salama (1996) have suggested the following categorisation and treatment options for increased gingival display as shown in Table 3.9. Waldrop (2008) has an interesting and up-to-date article on the challenges of managing gingival excess.

<table>
<thead>
<tr>
<th>Gingival or mucosal display</th>
<th>Degree</th>
<th>Treatment options</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-4 mm</td>
<td>1</td>
<td>orthodontic intrusion, orthodontics and periodontics, periodontics and restorative dentistry</td>
</tr>
<tr>
<td>4-8 mm</td>
<td>2</td>
<td>periodontics and restorative dentistry, orthognathic surgery</td>
</tr>
<tr>
<td>&gt; 8 mm</td>
<td>3</td>
<td>orthognathic surgery, with periodontics and restorative dentistry, where necessary</td>
</tr>
</tbody>
</table>

Table 3.9: Categorisation and treatment options for increased gingival display

Botulinum toxin type A (Botox)

Many patients with excessive gingival display have excessive muscle contraction. The use of Botulinum toxin A (BTX-A) to reduce gingival display is described by Polo (2008). Botulinum toxin type A is the most potent and most commonly used of the seven serotypes of BTX. BTX-A blocks neuromuscular transmission by binding to acceptor sites on motor or sympathetic nerves and thus preventing the release of acetylcholine. It therefore produces partial chemical denervation of the muscle with a consequent decrease in muscle activity. The
muscles injected were the elevators of the upper lip – *levator labii superioris alaeque nasi*, *levator labii superioris* and *zygomaticus minor*. The BTX-A was diluted by adding 4.0 mL normal saline solution to 100 units of vacuum dried BTX-A to give 2.5 units per 0.1 mL. Under sterile conditions, 2.5 units were injected into the overlapping points of the right and left *levator labii superioris alaeque nasi* and *levator labii superioris*, and *levator labii superioris* and *zygomaticus minor* (two injections per side, four injections per individual). The injection sites were identified by observation during smiling and palpation. Measurements of gingival display and upper central incisor height were recorded for each patient with a full, unposed, spontaneous smile. The results are shown in Figure 3.11; completers were patients who attended all seven follow-up appointments.

The results showed that from a mean pre-injection exposure of 5.2 mm, the gingival display declined to 0.09 mm two weeks post-injection – a reduction in gingival display of 5.1 mm. At the 24 week review, the mean gingival display had risen to just under three mm. We have not tried this technique but this is an interesting and thought-provoking paper and the comments of Niamtu (2008) are worth reading.

**Lip asymmetry**

Gazit-Rappaport et al (2003) measured the asymmetry and length of the lips in patients with functional side shifts (crossbites with lateral displacements). They used clinical photographs and divided the upper and lower lips into right and left hand sides with a vertical line down the centre of the philtrum; this line was used to measure vertical lip length. Horizontal lip length was measured along the junction of the upper and lower lips. The results for each quadrant were expressed as a percentage of the total surface area and length of each lip. In addition an absolute measure of lip asymmetry was used involving the difference between the right and left quadrants expressed as a percentage of the total lip surface area. Functional side shifts were shown to demonstrate measurable lip asymmetry characterised by thickening of the lower lip and thinning of the upper lip on the side of the shift.

**Maxillary cant**

The plane of the maxilla should be parallel to the interpupillary line when the patient is viewed in a full-face orientation. In fact the maxilla has two planes – a posterior occlusal plane and anterior (incisal) plane. If the posterior occlusal plane is not parallel to the interpupillary line, then it is likely that there is mandibular asymmetry (due to condylar hyperplasia?) with compensatory overdevelopment of the maxilla on one side. This situation is, of course, only treatable with surgery. However, if the posterior occlusal plane is parallel to the interpupillary line and the anterior occlusal plane is not, then this should be manageable by orthodontic treatment alone. Whether this requires extrusion or intrusion of the anterior teeth will depend on the crown lengths of the anterior teeth. The diagnosis and management of maxillary cant therefore depends on the interplay of four factors:

- interpupillary line
- posterior occlusal plane
- anterior occlusal plane
- maxillary incisor crown length

Kokich (1993b) has published an excellent article describing this in more detail.

**The relationship between occlusal outcome and smile aesthetics**

One of the tenets of Angle’s teaching was that if the teeth were put in the right place, then good soft tissue aesthetics would follow. Not all orthodontists necessarily accept this and Schabel et al (2008) studied the correlation between post-treatment smile aesthetics and the ABO Objective Grading System. They found no correlation between post-treatment smile aesthetics and the ABO Objective Grading System scores and that none of the individual components or summed scores of the system could predict attractive or unattractive smiles.

Pithon et al (2014) studied whether patients with dental aesthetics had any influence on obtaining a job. The authors found that people with ideal smiles are considered more intelligent and have a greater chance of finding a job when compared with persons with non-ideal smiles. Patients are often motivated by dental aesthetics, rather than by improvement in masticatory function suggesting that the psychological and social gains from orthodontic treatment have begun to be more significant than gains in oral health.
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