The anterior alveolus: its importance in limiting orthodontic treatment and its influence on the occurrence of iatrogenic sequelae

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A delineation of the limits of orthodontic tooth movement prior to the start of treatment would be extremely beneficial. Treatment planning would be greatly enhanced, especially in situations where the skeletal discrepancy is severe or where one or both arches can accommodate only limited tooth repositioning.

The question arises as to which patients can successfully be treated with orthodontic therapy alone and which patients will also require orthognathic surgery.[1-3] The decision in borderline cases is frequently based on whether orthodontic treatment will result in acceptable facial esthetics. However, the orthodontist must also consider whether sufficient orthodontic tooth movement can be accomplished to correct the malocclusion, and whether this movement can be performed with minimal iatrogenic tissue loss.

The incidence of bone loss and root resorption in adult orthodontic patients is, in general, at a level that is clinically acceptable, although losses in individual cases could compromise the dentition.[4-5] The hypothesis of this paper is that as the teeth are repositioned at their anatomic limits, the occurrence and severity of iatrogenic phenomena is enhanced. Thus, it is the occurrence of serious, unfavorable sequelae that may establish the limits of orthodontic treatment and define the borderline case as "orthodontic" or "surgical-orthodontic."

Our ability to move teeth within the limits of the alveolar trough is confirmed daily in orthodontic practice with bodily retraction of canines in premolar extraction cases. Less clear, however,

Abstract

Delineating the limits of orthodontic treatment in nongrowing individuals is important when making treatment decisions, especially in borderline orthodontic-surgical cases. The labial and lingual cortical plates at the level of the incisor apex may represent the anatomic limits of tooth movement. Cephalometric films of 107 adults were measured to determine the width of alveolar bone anterior and posterior to the incisor apex in each arch. Thin alveolar widths were found both labial and lingual to the mandibular incisors in groups of Class I, II, and III individuals with high SN-MP angle and in a group of Class III average SN-MP individuals. Thin alveolar widths were also found lingual to the maxillary incisors in a Class II high angle group.

Clinical cases are presented showing that orthodontic tooth movement may be limited in patients with narrow alveolar bone widths and that these patients are likely to experience increased iatrogenic sequelae.

Key Words

Alveolar width • Facial type • Borderline surgical case • Iatrogenic loss.

Submitted: May 1995 **Revised and accepted:** September 1995 Angle Orthod 1996;66(2):95-110.

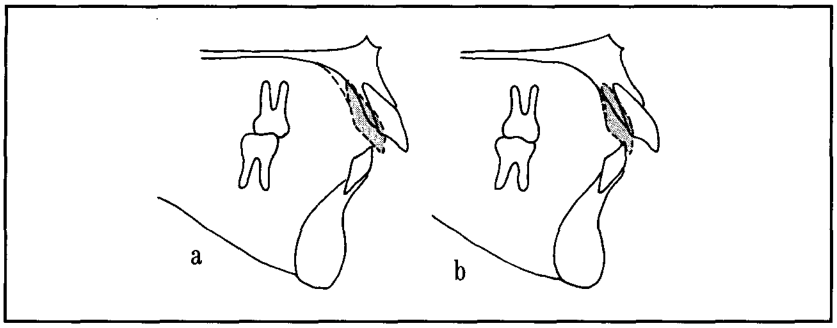

Figure 1A-B

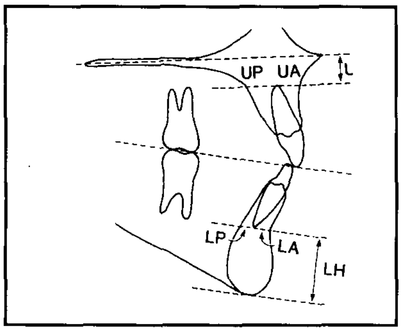

Figure 2

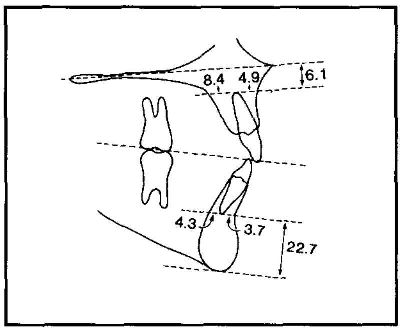

Figure 3

Figure 1A-B
After Edwards.[7]
A: The assumption is that the total alveolus can remodel to accommodate unlimited tooth movement. This is not seen in clinical practice.
B: The assumption is that only the midroot and marginal alveolus can remodel, while the bone at the level of the apex does not remodel and is thus a limit to orthodontic tooth movement.

Figure 2
Cephalometric measurements that define the width and height of the incisor alveolus.

Figure 3
Class I average skeletal pattern. The mean for each alveolar measurement is illustrated.

is our ability to bodily retract incisors over similar distances. Unlimited tooth movement assumes that the osseous housing can fully reconstitute itself in any direction the tooth is moved (Figure 1A). However, clinical experience indicates that some limitation to anterior-posterior incisor movement is operative (Figure 1B). Proffit and Ackerman[6] presented a theoretical model of the limitations of orthodontic correction in the form of three concentric "envelopes of discrepancy." The inner envelope represents the limits of orthodontic tooth movement; the middle, changes that are possible with growth; and the outer envelope, the limits that can be achieved via orthognathic surgery. While the authors put numbers on the limits of the inner envelope, their purpose was to illustrate the principle of limitation and was not based on measurements or specific anatomic barriers.

Edwards[7] studied a large group of individuals with Class II malocclusion and bidental protrusion. He noted that despite prolonged palatal retraction and root torquing of incisors, the width of the anterior palate at the level of the apex remained unchanged. The alveolus can, however, remodel at the mid-root level and at the alveolar margin when the lingual cortex is approached and passed. He postulated an anatomic barrier against further tooth movement in the higher areas at the anterior palatal curvature as it approaches the horizontal vault (Figure 1B).

Edwards also pointed out the great variability in the width of the alveolar process supporting the maxillary incisors and illustrated the limitation placed upon orthodontic treatment by a thin alveolus.

He measured the labiolingual width of the anterior portion of the palate and stated that there does not appear to be a statistically significant difference in these measures for groups segregated by mandibular divergence (SN-MP).

Ten Hoeve and Mulie [8] studied tooth movement at each stage of the Begg technique in a group of adolescent patients. In addition to cephalometric x-rays, they used laminagraphs to better visualize the thin bone palatal to the repositioned incisors. They noted that maxillary incisors respond favorably to the initial torque force of stage 3 mechanics, then remain at a standstill for several months when the apex approximates the dense cortical plate. Further torque force results in the incisor sliding occlusally and forward rather than achieving true lingual root torque. A characteristic type of labial root resorption was noted after stage 1. At the end of stage 3, root resorption also extended from the apex along the palatal root surface. Laminagrams revealed the presence of a thin layer of cortical bone in the marginal area on the lingual side of the alveolar process that often could not be seen in cephalometric x-rays. Ten Hoeve and Mulie concluded that while there is no anatomical limit to tooth movement in the marginal area of the alveolus, there is a definite limit to tooth movement as the apex abuts the palatal cortex.

Mulie and Ten Hoeve[9] performed a similar study of tooth movement in the mandibular symphysis. They stated that following contact of the root with the lingual cortical plate of the symphysis, tooth movement comes to a standstill. Eventually, if greater forces are applied, a perforation or dehiscence results.

Ten Hoeve and Mulie demonstrated that anatomic limitations in the palate and symphysis are associated with iatrogenic sequelae when these limits are challenged. The sequelae noted in their sample of adolescents was limited to resorption of the root of the maxillary and mandibular incisors and perforation of the lingual cortical plate of the mandibular symphysis.

The dimension of the anterior alveolus appears to set limits to orthodontic treatment, and challenging these boundaries may accelerate iatrogenic sequelae. A study was therefore undertaken to establish cephalometric norms for the width of the anterior alveolus around the maxillary and mandibular incisors. The data was segregated according to various skeletal facial types to see if skeletal form is a determinant of anterior alveolar width. Some clinical examples are presented to demonstrate a possible linkage between anterior alveolar width and iatrogenic experience.

Materials and methods

Pretreatment lateral cephalometric films from a private orthodontic practice were secured for 107 Caucasians (30 males and 77 females) who were past the age of 19 years. Patients requiring orthognathic surgery were not excluded from the study. Films were selected serially from the most recent patient records and divided by facial type into three vertical and three horizontal groups. The vertical criterion was the sella-nasion to mandibular plane (SN-MP) angle, with the average group measuring from 30° to 37°; the low group ≤ 28°, and the high group ≥ 39°. Individuals measuring 29° or 38° were excluded from the study. Because of the scarcity of Class III patients, it was necessary to extend the serial record search several additional years to collect a sample of these patients. The division into three horizontal and three vertical groups resulted in nine subgroups (Table 1), similar to the classification proposed by Sassouni.[10]

The measurements used in this study are illustrated in Figure 2 and are defined below. They were recorded to the nearest 0.5 mm.

UP - Bone posterior (lingual) to upper incisor apex. Apex of the maxillary central incisors to the limit of the palatal cortex, along a plane parallel to the palatal plane, drawn through the apex.

UA - Bone anterior (labial) to upper incisor apex. Apex of the maxillary central incisors to the limit of the labial cortex, along a plane parallel to ANS-PNS, drawn through the apex.

LP - Bone posterior (lingual) to mandibular incisor apex. Apex of the mandibular central incisor to the limit of the lingual cortex, along a plane parallel to the occlusal plane, drawn through the apex.

LA - Bone anterior (labial) to mandibular incisor apex. Apex of the mandibular central incisors to the limit of the labial cortex, along a plane parallel to the occlusal plane, drawn through the apex.

UH - Bone superior to upper incisor apex. The shortest distance from the maxillary incisor apex to the ANS-PNS plane.

LH - Bone inferior to mandibular incisor apex. The shortest distance from the apex of mandibular incisor apex to the lowest point on the mandibular synthesis that is transected by a line parallel to occlusal plane.

Table 1
Number of subjects in nine subgroups defined by Angle classification and mandibular divergence, SN-MP (n = 107)

	Low	Average	High
Class I	15	18	15
Class II	12	7	10
Class III	7	9	12

Data analysis

Analysis of variance was carried out, followed by Scheffé tests to detect pairwise difference among means. Significance was established at the 0.05 level.

Results

Segregating the data by Angle classification (Table 2) resulted in similar measures for incisor position in the alveolus, with the following exceptions: Bone levels superior to the maxillary incisor apex (UH) and inferior to the mandibular incisor apex (LH) were greater in the Class III group than in the Class I group, and the bone level lingual to the mandibular incisor apex (LP) was narrower in the Class III group than in the Class I or II groups.

Segregation of the data by mandibular divergence (Table 3) resulted in several significant differences at the 0.05 level. The width of the bone lingual to the maxillary incisor apex (UP) was greater in the low SN-MP group than in either the average or high SN-MP groups. Bone lingual to the mandibular incisor apex (LP) was wider in the low angle group than in either the average or high angle groups. Bone labial to the mandibular incisor apex (LA) was narrower in the high SN-MP group than in the average or low SN-MP groups. The total width of the mandibular alveolus (LP + LA) was significantly wider in the low SN-MP group and narrowest in the high SN-MP group. The height of the alveolus superior to the maxillary incisor apex (UH) and inferior to the mandibular incisor apex (LH) was greater in the high SN-MP group than in the average or low SN-MP groups.

When the 107 subjects were segregated into nine subgroups, the number of subjects in each subgroup was small and there were few statistically significant differences in variables among the Class I average SN-MP group and the eight other subgroups. This data is not presented. It appeared, however, that the width of bone around the incisors was frequently thin in cer-

Table 2
Width and height of the anterior alveolus and Angle classification

Variable	Class I N = 48	Class II N = 29	Class III N = 30
SN - MP	33.6 ± 9.1	32.7 ± 8.4	35.9 ± 8.5
UP	9.1 ± 3.1	8.2 ± 2.9	7.9 ± 2.1
UA	4.3 ± 1.3	4.8 ± 1.4	4.8 ± 1.2
UP + UA	13.4 ± 2.9	12.9 ± 2.7	12.7 ± 2.7
LP	4.3 ± 1.5	4.2 ± 1.3+	3.0 ± 1.7*
LA	3.4 ± 1.3	3.1 ± 1.5	2.7 ± 1.2
LP + LA	7.6 ± 2.1	7.3 ± 2.0+	5.6 ± 2.5
UH	6.5 ± 3.0	7.4 ± 2.8	9.2 ± 2.8*
LH	23.2 ± 3.5	24.2 ± 4.0	25.4 ± 3.6*

*P < 0.05 for comparisons with average group
+ P < 0.05 for comparison of Class II and Class III groups

Table 3
Width and height of the anterior alveolus and mandibular divergence, SN-MP

Variable	Low (N = 34)	Average (N = 36)	High (N = 37)
SN - MP	24.2 ± 3.5*+	33.5 ± 2.0	44.2 ± 5.1
UP	10.3 ± 3.3 *+	8.1 ± 2.2	7.3 ± 2.0
UA	4.4 ± 1.5	4.6 ± 1.3	4.7 ± 1.2
UP ± UA	14.7 ± 2.9 *+	12.7 ± 2.3	12.0 ± 2.4
LP	5.0 ± 1.3*+	3.7 ± 1.6	3.1 ± 1.4
LA	3.8 ± 1.3+	3.3 ± 1.3	2.3 ± 1.0*
LP + LA	8.7 ± 1.9*+	7.0 ± 2.2	5.5 ± 1.8*
UH	5.8 ± 2.6 +	7.1 ± 2.9	9.5 ± 2.5*
LH	22.2 ± 3.2+	23.5 ± 3.2	26.5 ± 3.4*

*P < 0.05 for comparisons with average group
+ P < 0.05 for comparison of low and high groups

tain subgroups. Since thinness of the alveolus was thought to be clinically relevant, the distribution of narrow alveolar bone in the nine subgroups was studied. A thin alveolus was defined as equal to or less than one standard deviation below the mean of the Class I average SN-MP group (Tables 4 and 5). A normal probability curve would predict that 16% of the data would be < 1 S.D. of the mean. A high percentage of subjects (46-90%) in the three high SN-MP groups and the Class III average group had thin alveolar bone both labial and lingual to the mandibular incisors. In contrast, the Class III low SN-MP group did not demonstrate this thin LA-LP pattern. Bone lingual to the maxillary incisor (UP) was frequently (40%) thin in the Class I and Class II high SN-MP groups (Table 5).

A thin alveolus may be noted on an individual basis in almost any group, even the Class I average group. However, the Class I and Class II average SN-MP groups and all three low SN-MP groups tended to have a minimal number of subjects with a narrow alveolus.

Alveolar width

Subdividing the sample of 107 adults by Angle classification resulted in few significant differences in the width of bone labial or lingual to the maxillary or mandibular incisor apices. When the sample was subdivided by mandibular divergence (SN-MP), however, several dimensions were significantly different (Table 3). This finding is in contrast to that of Edwards,[7] who found no difference in width of the anterior alveolus in groups divided by mandibular divergence. When compared with the average SN-MP group, the high angle groups had narrower bone labial to the mandibular incisor while the low angle groups had wider bone lingual to the maxillary and mandibular incisors.

Analysis of the subgroups that had thin alveolar width, that is ≤ 1, S.D. of the Class I average group mean, shows that the three high angle groups and the Class III average group tend to show a large number of subjects with thin alveolar widths. On the other hand, the low SN-MP groups tend to have few subjects with thin alveolar widths. There appears to be a direct relationship between increased facial and alveolar height and thinness of the alveolar bone. Apparently, as a consequence of facial height increase, the incisors erupt to maintain overbite, and the alveolus becomes attenuated with thinning of the width between labial and lingual walls.

Isaacson et al.[11] studied three groups—high, average, and low SN-MP—that were selected in a fashion similar to this paper. Lower facial height

(ANS to menton) was different for the three groups; the low SN-MP group was 4.8 mm shorter than the average group and the high SN-MP group was 7.1 mm longer than the average group. In the present study, the height of bone superior to the maxillary (UH) and inferior to the mandibular incisor apices (LH) reflects mandibular divergence in a similar manner (Table 3). It appears that as the face lengthens, in part due to mandibular divergence, the incisors must erupt away from the basilar planes.

Dividing 103 patients into nine subgroups results in a small number of patients in each cell—as low as 7 and no higher than 18. This study needs to be repeated with a much larger sample to more accurately define subgroups. Differences between the sexes or racial groups were not considered in this study. A larger sample would also diminish the problem of assigning subjects to subgroups based on one cephalometric measure, with only 2° separating the high and low groups from the average.

More important than the group means is the unique variation of alveolar size for individuals and its effect on treatment. This is best illustrated by citing clinical cases. These cases will also demonstrate the possible association of thin alveolar housing and iatrogenic phenomena.

Class II with long lower face height

Individuals in the Class II high SN-MP group frequently have a thin zone of bone lingual to the maxillary incisors (Table 5). Reduction of maxillary incisor protrusion in individuals who have narrow UP widths will be limited. The limitation set by the palatal cortex is illustrated by a female patient, age 26 years 2 months, with a Class II malocclusion and 12 mm overjet (Figure 4A-H). Although the SN-MP was normal at 33°, this patient had excessive facial height (Figure 4G). The bone superior to the maxillary incisors was 13.5 mm (norm UH = 6.1 mm) and the lower face height was excessive at 78 mm. Bone lingual to the maxillary incisors, at 4.5 mm, was narrow (norm UP = 8.4 mm) and insufficient to correct an overjet of 12 mm without excessive uprighting of the incisors. Bone lingual to the mandibular incisor was only 2.5 mm, with 3.7 mm as the norm. The maxillary incisors were protrusive with an anterior openbite, and the mandibular incisors were crowded (Figure 4B).

The maxillary first premolars and one mandibular incisor were extracted to allow for correction of the overjet and mandibular incisor crowding. Treatment time was 23 months. The overjet was reduced 11 mm, partly by retraction and partly by uprighting of the incisors (Figure

Table 4
Mean ± S.D. of width of bone supporting incisors for Class I average SN-MP group (n=18)

UP	8.4 ± 2.4
UA	4.9 ± 1.1
UP + UA	13.3 ± 2.3
LP	4.3 ± 1.3
LA	3.7 ± 1.2
LP + LA	7.9 ± 1.6
UH	6.1 ± 2.6
LH	22.7 ± 2.3

Table 5
Percent of subjects of facial type subgroups with alveolar width ≤ 1 S.D of the norm*

SN-MP	Class	N	UP	UA	LP	LA
Average	I	18	22	6	22	22
	II	7	29	29	22	43
	III	11	18	9	73	64
Low	I	15	0	13	0	20
	II	12	17	17	0	33
	III	7	14	0	0	29
High	I	15	40	20	46	73
	II	10	40	10	50	90
	III	12	25	05	58	67

*norm is Class I average in mm

Figure 4A-B
Pretreatment portraits and intraoral photo of a 26-year-old female. See text under Class II long lower face height. Note lip incompetence, anterior openbite, maxillary dental protrusion, and mandibular incisor crowding.

Figure 4A

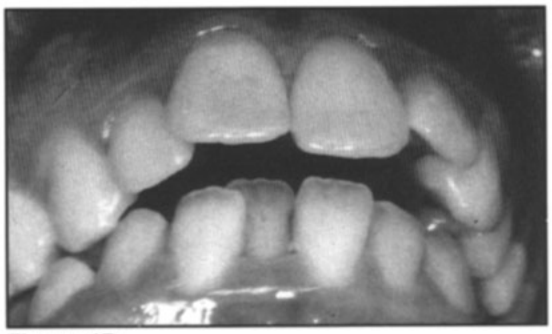

Figure 4B

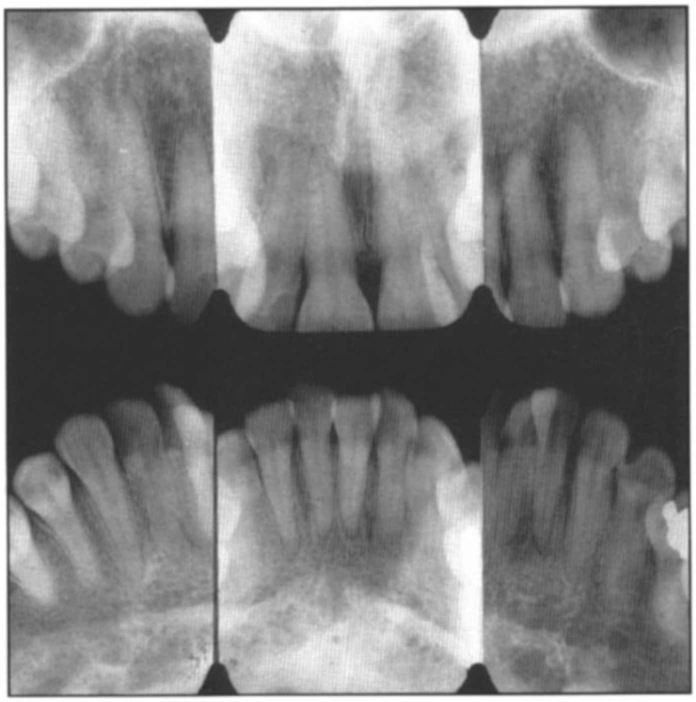

Figure 4C

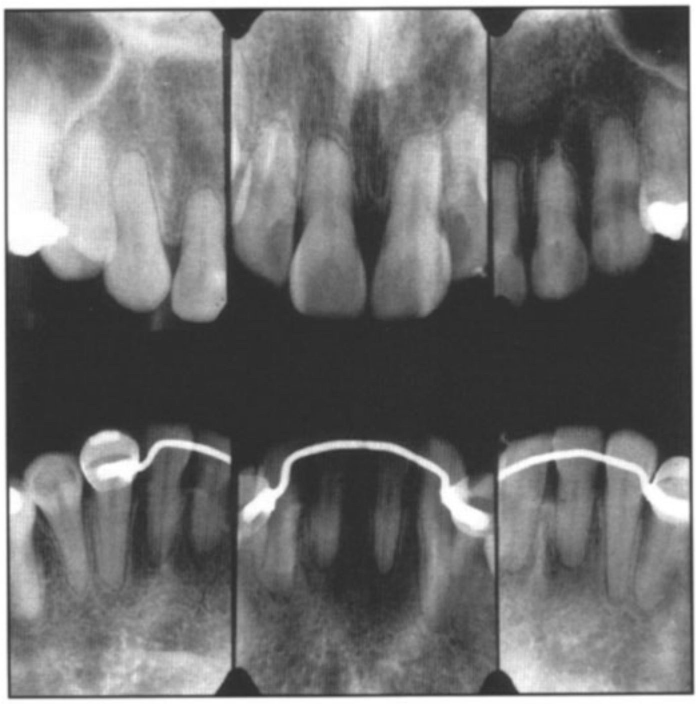

Figure 4F

Figure 4C
Pretreatment periapical x-rays of the incisors.

Figure 4F
Posttreatment periapical radiographs of the incisors. Note the root resorption of the maxillary incisors and marginal bone loss around the mandibular incisors consistent with the insufficient width of the alveolar bone lingual to the maxillary incisors and the thin lower alveolus.

4H). The maxillary incisor apices were positioned at the limit of the palatal cortex. The mandibular incisors were moderately repositioned in a lingual direction. Posttreatment radiographs (Figure 4F) reveal significant maxillary incisor root resorption and moderate marginal bone loss. The mandibular incisors show moderate root resorption but significant (about 2-3 mm) marginal bone loss. The soft tissue profile was greatly improved , but upper gingival exposure increased (Figure 4D and H).

The bone loss and root resorption can be attributed, in part, to movement of the maxillary incisors to the limits of the palatal cortex and to the thin attenuated alveolar bone in both arches. This patient was treated in the early 1970s. Today, a recommendation of maxillary surgery would be included in her treatment plan.

Class III average and high SN-MP groups

The Class III high and average SN-MP groups have thin alveolar bone widths labial and lingual to the mandibular incisor apices and thin alveoli labial to the maxillary incisors. This makes both labial expansion of the mandibular incisors (often done prior to orthognathic surgery) as well as lingual retraction of the mandibular incisors and labial expansion of the maxillary incisors (as in orthodontic compensation) quite hazardous.

A male patient, 27 years old, with a Class III malocclusion and a long vertical development of the face is illustrated in Figure 5A-J. The width of the mandibular arch, especially in the canine region, was excessive relative to the maxillary arch. The anterior occlusion was only moderately in crossbite due to the labial inclination of the maxillary incisors and lingual inclination of the mandibular incisors. The width of bone labial and lingual to the maxillary incisor apex was close to the norm (Figure 5G). The width of bone labial (2.0 mm) and lingual (1.5 mm) to the mandibular incisor apex was extremely thin. The mandibular plane at 35° does not demonstrate a

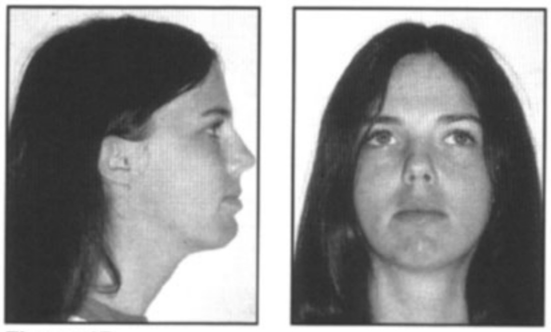

Figure 4D

Figure 4E

Figure 4D-E
Posttreatment portraits and intraoral photograph. Treatment was completed in 23 months. The maxillary first premolars and one mandibular incisor were extracted. Note improvement in the profile and correction of the openbite and dental protrusion.

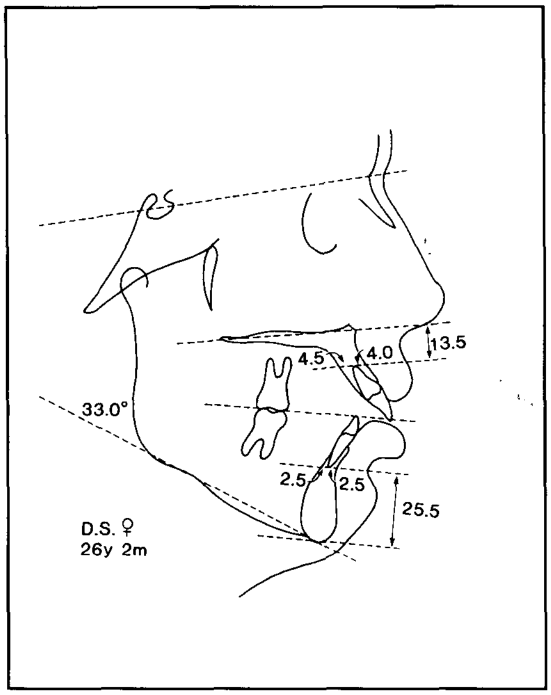

Figure 4G

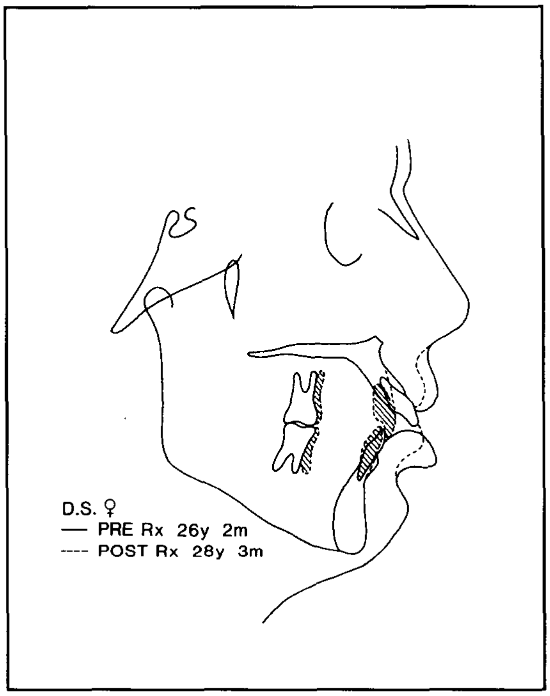

Figure 4H

Figure 4G
Tracing of the pretreatment cephalometric x-ray with alveolar dimensions recorded. Compare with Figure 3. Note narrow bone palatal to the maxillary incisors and very narrow alveolus around the mandibular incisors. The 4 mm UP-width is insufficient when the 12 mm overjet is considered.

Figure 4H
Tracing of superimposed pretreatment and posttreatment cephalometric x-rays shows the maxillary incisors were retracted to the limit of the palatal cortex.

long face pattern, but the bone superior and inferior to the maxillary and mandibular incisors apices exceeds the norm, and the lower facial height was long at 86 mm.

The mandibular canines were extracted because of extensive recession of the attached gingiva and dehiscence of the labial bone (Figure 5B). Treatment time was 23 months.

The posttreatment records show that the mandibular incisors were moved in a lingual direction about 3 mm at the crown and 1.5 mm at the apex, which placed them at the limit of the symphysis (Figure 5H). The width of the mandibular arch lingual to the lateral incisor was narrowed by 7 mm. Root resorption is evident on the maxillary incisors (Figure 5F). There is moderate bone loss (1 mm) around the maxillary incisors. The mandibular incisors show significant root resorption as well as severe bone loss. Bone loss is generally about 2 mm, but extends to 4 mm at the distal of the right lateral incisor. Labial gingival recession of the mandibular incisors following treatment is noted (Figure 5E). The posttreatment soft tissue profile is excellent (Figure 5D).

The combination of root resorption and marginal bone loss resulted in mobility of the mandibular incisors. This mobility was controlled by a lingual retainer bonded to all incisors extending to the second premolar (Figure 5I). The combination of a thin pretreatment alveolus and the extensive narrowing of the mandibular arch may have initiated a marked iatrogenic reaction at both the apex and the marginal bone of the mandibular incisors.

The mandibular lingual bonded retainer has been in place to date, and the mandibular incisors have been maintained without any further loss of root length or periodontal support for 10 years (Figure 5J).

Figures 5A-B
Pretreatment portraits and intraoral photo of a 27-year-old male. See section on Class III average and high SN-MP groups. Note acceptable profile despite Class III molar occlusion. Also note gingival recession of the canines, especially the mandibular canines.

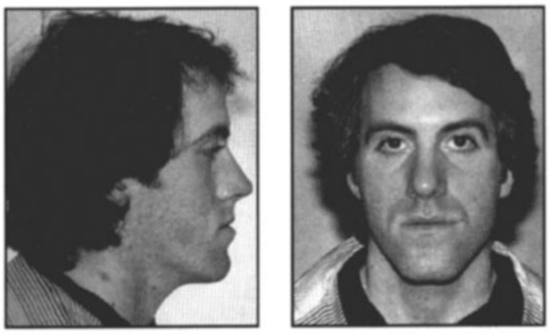

Figure 5A

Figure 5B

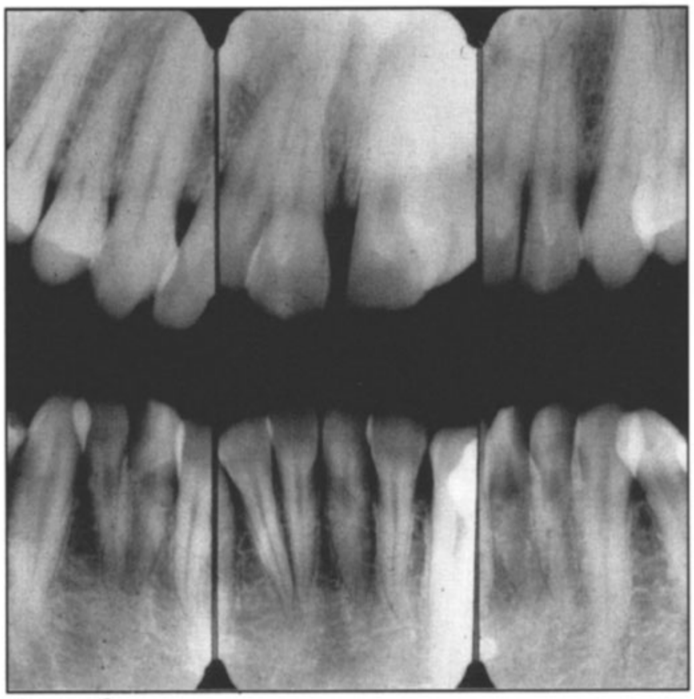

Figure 5C

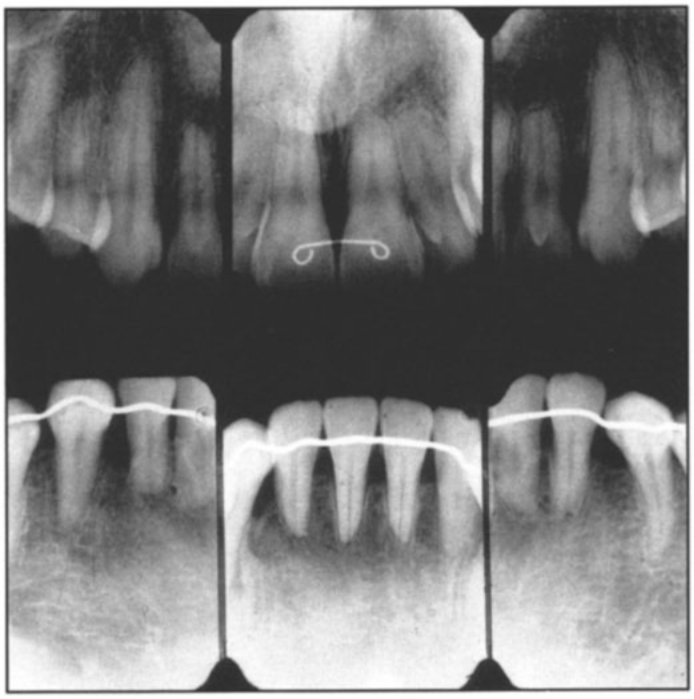

Figure 5F

Figure 5C
Pretreatment periapical x-rays of the incisors.

Figure 5F
Posttreatment periapical x-rays of the incisors. Note the severe root resorption as well as bone loss around the mandibular incisors despite their modest movement. This is consistent with the presence of a thin alveolus over the mandibular incisors.

Class III groups

Sperry et al.[12] studied a mixed group of patients with Class III malocclusion treated without orthognathic surgery by increasing dental compensations, i.e., by inclining the maxillary incisors labially and the mandibular incisors lingually, similar to the treatment in the previous case. They noted gingival recession on the labial of both arches, especially the mandibular arch.

Årtun and Krogstad[13] studied adults with Class III malocclusion treated with orthodontic decompensation of the mandibular incisors prior to orthognathic surgery. They demonstrated that excessive labial proclination of mandibular incisors may lead to gingival recession, particularly when the alveolar housing, measured across the symphysis at the level of the incisor apex, is narrow.

Individuals in the Class III low SN-MP group usually do not have a narrow anterior alveolus. This is in contrast to the Class III average and high SN-MP groups (Table 5). The low SN-MP subject may show less iatrogenic phenomena, i.e., bone loss, root resorption, or gingival recession, when treated by labial expansion of the mandibular arch prior to orthognathic surgery, or, in mild A-P cases, following retraction of the mandibular incisors. This hypothesis is supported by Årtun and Krogstad[13] in terms of gingival recession and a thin alveolus. Future studies are needed in which periapical x-rays are also evaluated so that bone loss and root resorption can be studied.

Bimaxillary dentoalveolar protrusion

Edwards (his Figures 26 and 27)[7] pointed out that many severe bimaxillary protrusion subjects have thin alveolar bone. Three examples of severe bimaxillary protrusion are illustrated in lateral cephalometric views (Figure 6A-C). All three patients have dental protrusion, narrow alveolar width, excessive lower face height, divergent

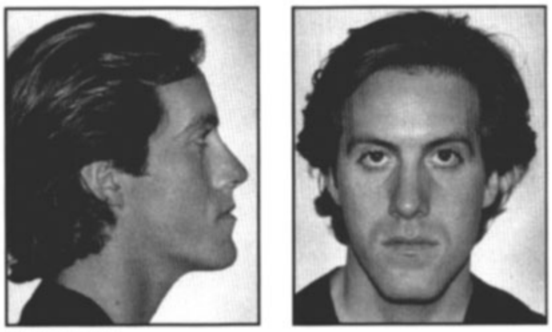

Figure 5D

Figure 5E

Figures 5D-E
Posttreatment portraits and intraoral photograph. Treatment time was 23 months. The mandibular canines were extracted. Note improvement of the profile because the lower lip flattened along with the retraction of the mandibular incisors. The occlusion is much improved. The mandibular right central incisor shows moderate gingival recession.

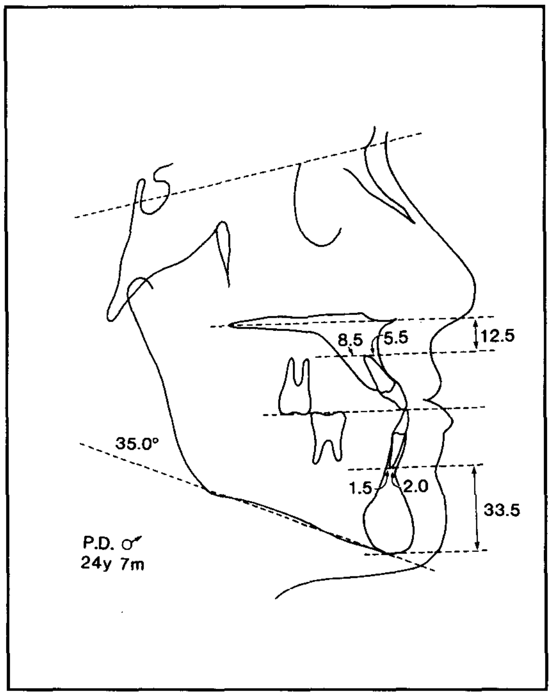

Figure 5G

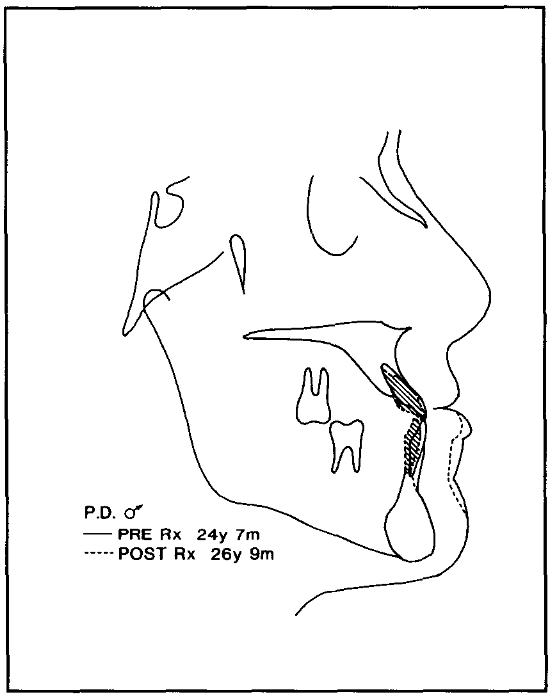

Figure 5H

Figure 5G
Tracing of pretreatment cephalometric x-ray with alveolar dimensions recorded. Compare with Figure 3. Note the normal width of alveolar bone about the maxillary incisors and the extremely thin alveolar bone about the mandibular incisors.

Figure 5H
Tracing of the superimposed pretreatment and posttreatment cephalometric x-rays. The mandibular incisors were moved 3 mm at the level of the crown and only 1.5 mm at the apex.

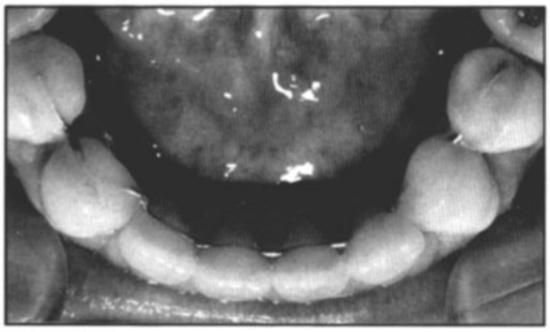

Figure 5I

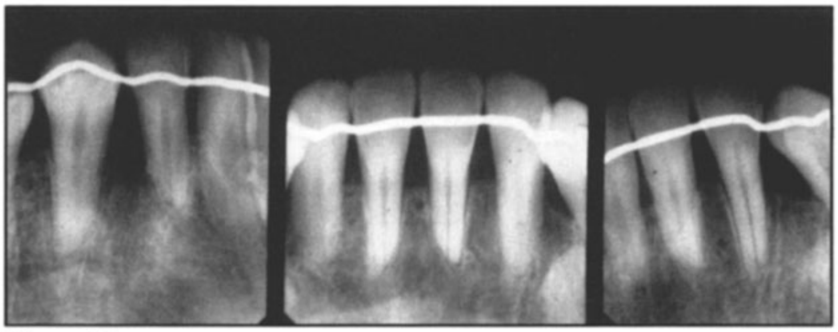

Figure 5J

Figure 5I
Posttreatment occlusal view of the mandibular arch. A lingual wire was bonded to all teeth from second premolar to second premolar.

Figure 5J
Periapical x-rays taken 10 years postretention. Note stability of the periodontium.

mandibular planes, and lip incompetence. It would be unwise to attempt orthodontic treatment for profile improvement for these patients without surgery because of insufficient alveolar bone to accommodate the required retraction of the incisors. This anatomic limitation would also place the patients at risk for iatrogenic sequelae.

A patient with bimaxillary dentoalveolar protrusion, lip incompetence, and a protrusive dental profile is illustrated in Figure 7A-D. The patient's chief concern was poor facial esthetics due to the protrusive dentition and fullness of the lips (Figure 7A,C). She was treated with a combined orthodontic-surgical approach that included extraction of the four first premolars followed by maxillary and mandibular segmental alveolar osteotomies to close the extraction sites and reduce the dental protrusion. The postsurgical tracings (Figure 7D) demonstrate that surgery allowed repositioning of the mandibular

Figures 6A-C
Tracing of cephalometric x-rays of three adult patients who presented for orthodontic treatment because of bimaxillary dentoalveolar protrusion. All three patients have severe dental protrusion, excessive lower facial height, divergent mandibular planes, and lip incompetence. The alveolar width available for correction of the protrusions was judged inadequate (compare with Figure 3) and combined orthodontic-orthognathic surgical procedures were advised.

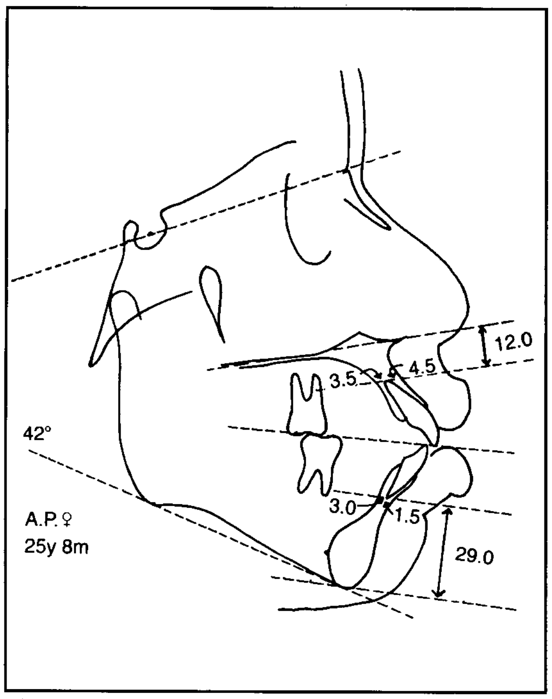

Figure 6A

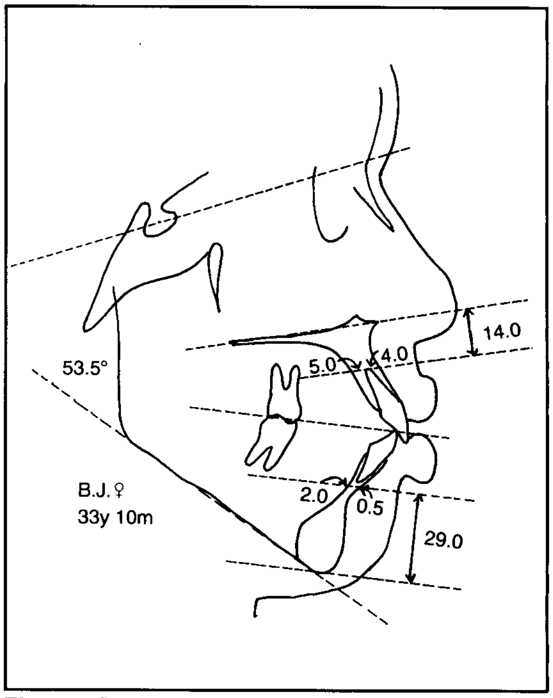

Figure 6B

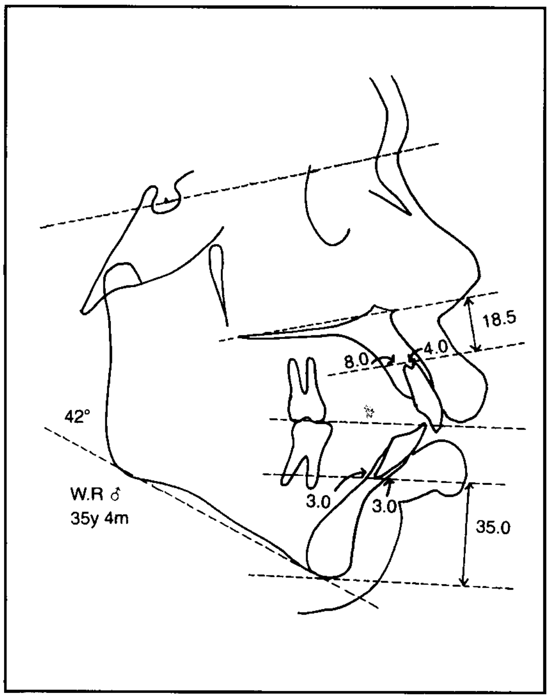

Figure 6C

incisors well beyond the cortical plate of the symphysis. The profile improvement was significant (Figure 7B). Treatment with orthodontics alone would have been limited by the mandibular synthesis to a modest profile change.

Repositioning teeth beyond the alveolar housing

Can the apex of the incisor roots be positioned beyond the alveolar housing? Will the cortical plate remodel or will the roots undergo resorption? Mulhe and Ten Hoeve,[9] as discussed previously, concluded that if the apex was moved beyond the alveolus, the cortex in that region would not significantly remodel and the lingual cortical plate of the symphysis could be perforated. A case is presented where the lingual plate was perforated dramatically (Figure 8A-I).

A 49-year-old postmenopausal Caucasian female presented with a Class II malocclusion with 5.5 mm overjet and a high mandibular plane skeletal pattern (Figure 8A and F). The mandibular incisors were severely crowded. The thickness of the alveolus around the maxillary incisors was adequate to accommodate overjet correction (Figure 8F). Bone around the mandibular incisors was thin at 3.9 mm, with the width of bone to the lingual only 0.9 mm (the norm for LP = 4.3 mm).

The patient was periodontally healthy at the time and could not be probed beyond 3 mm. There was, however, bone loss around the crowded mandibular incisors from past periodontal disease, which measured 3.5 mm from the CEJ (Figure 8B). The protrusion of the maxillary teeth and the crowding of the mandibular teeth resulted in a disfiguring malocclusion.

The treatment plan prescribed extraction of the maxillary right and left first premolars. In the mandibular arch, the left central was extracted to provide enough space to align the incisors. Premolar extraction in the mandibular arch was vetoed because it was felt that this would have required retraction of the incisors in the face of

Figure 7A

Figure 7B

Figure7A
Portraits taken prior to surgery on a 29-year-old female. See section on bimaxillary dentoalveolar protrusion. Note poor facial esthetics due to dental protrusion and lip incompetence. Also note gingiva showing upon smiling.

Figure 7B
Portraits taken after surgery at completion of treatment. Four first premolars were extracted and maxillary and mandibular segmental osteotomies were performed to reduce protrusion. Note improvement in profile and lip competence.

Figure 7C
Pretreatment tracing alveolar dimensions recorded, (compare with Figure 3). Alveolar bone lingual to the mandibular incisors will not accommodate sufficient retraction via orthodontic treatment for improvement of facial esthetics.

Figure 7D
Superimposed pretreatment and posttreatment cephalometric tracings. Note that combined orthodontic surgical treatment allowed reduction of the bidental protrusion as well as positioning of the mandibular incisors beyond the limits of the pretreatment lingual cortical plate of the synthesis.

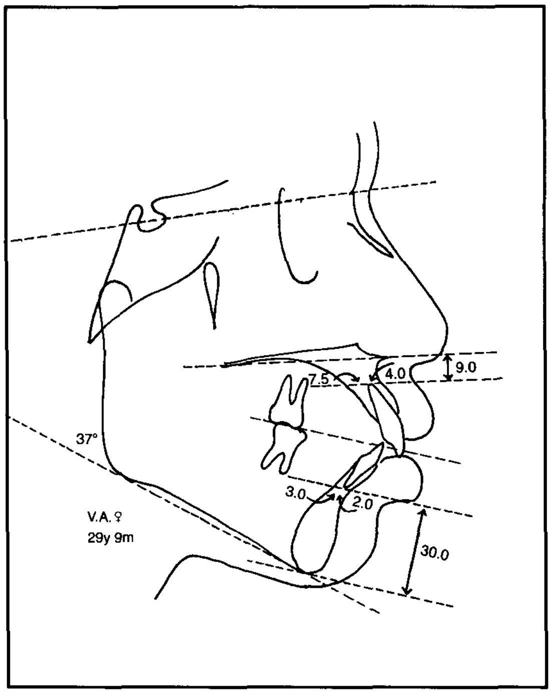

Figure 7C

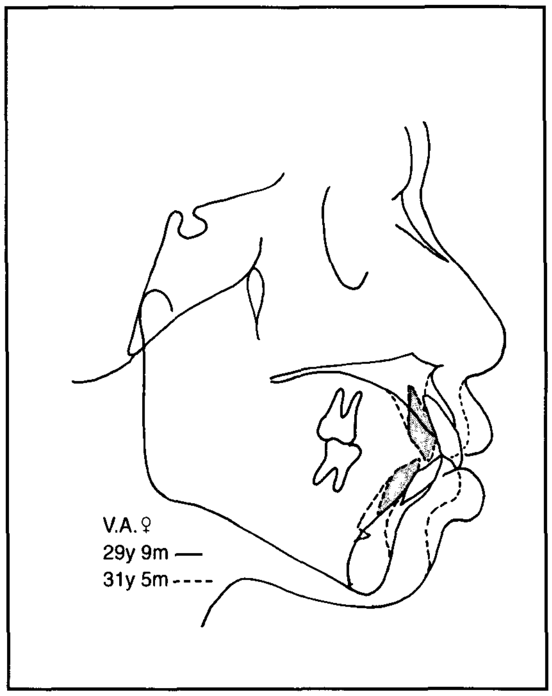

Figure 7D

almost no lingual alveolar bone.

At about the ninth month of treatment, the patient noted extreme mobility of the mandibular incisors. Although oral hygiene was poor, the periodontium could not be probed beyond pretreatment levels. Periapical x-rays taken at this time showed bone loss and moderate root resorption around the mandibular incisors (Figure 8D).

The mobility of the mandibular incisors continued. Thirteen months after the start of treatment, the incisors and canines were stabilized by a lingual bonded wire. Treatment was completed in 24 months, at which time the mandibular lingual bonded wire was extended to the premolars (Figure 8I).

Cephalometric x-rays were taken as part of the final records. At this time it was apparent the roots of the mandibular incisors were inadvertently torqued through the lingual cortical plate

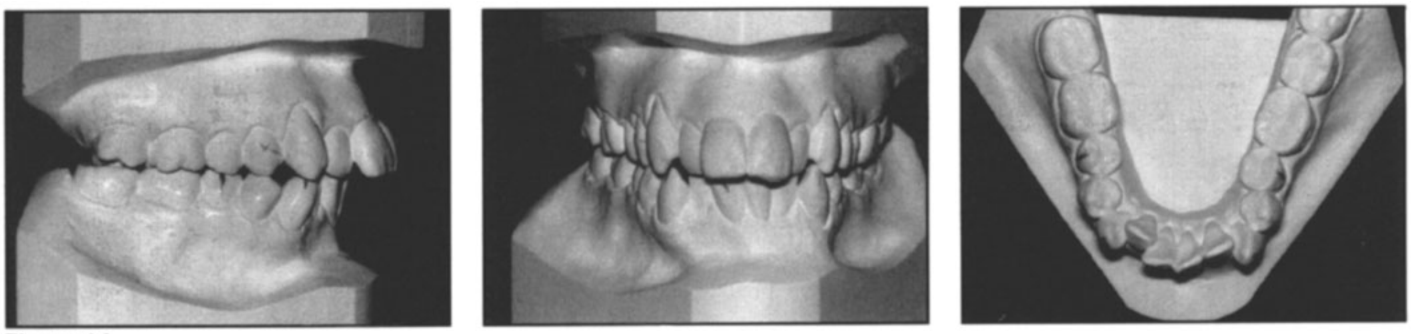

Figure 8A

Figure 8A
Pretreatment study models of a 49-year-old female. See section on repositioning teeth beyond the alveolar housing. Note severe overjet, Class II occlusion, and mandibular incisor crowding.

Figure 8B
Pretreatment periapical x-rays of the mandibular incisors. Note marginal bone loss around the mandibular incisors.

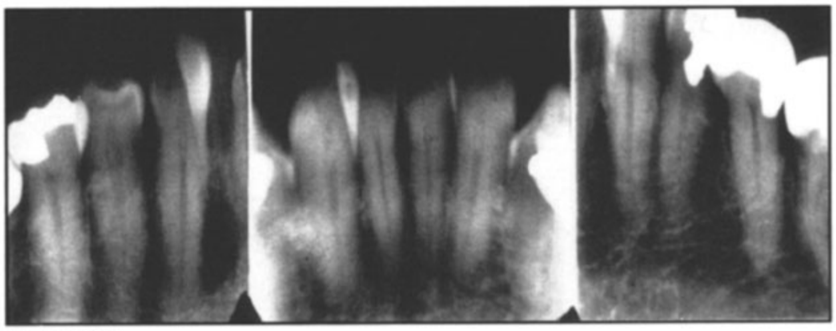

Figure 8B

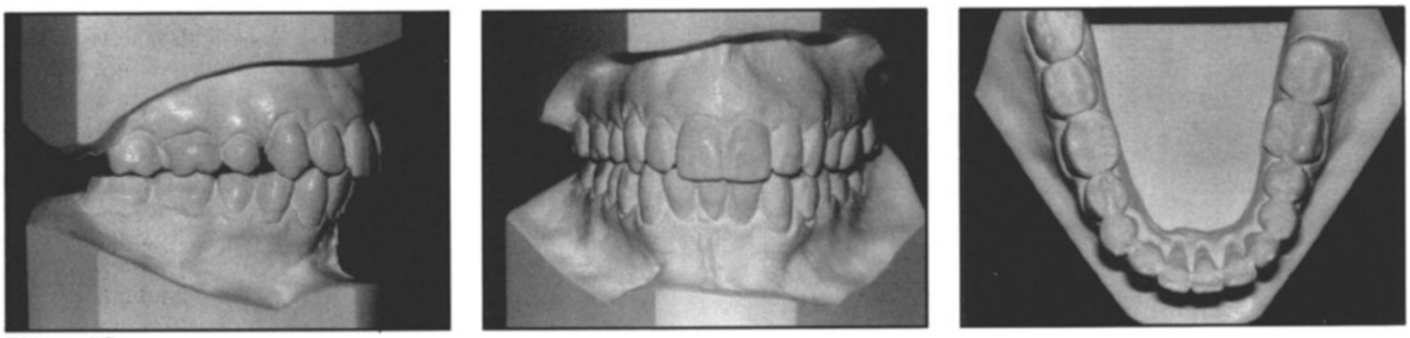

Figure 8C

Figure 8D

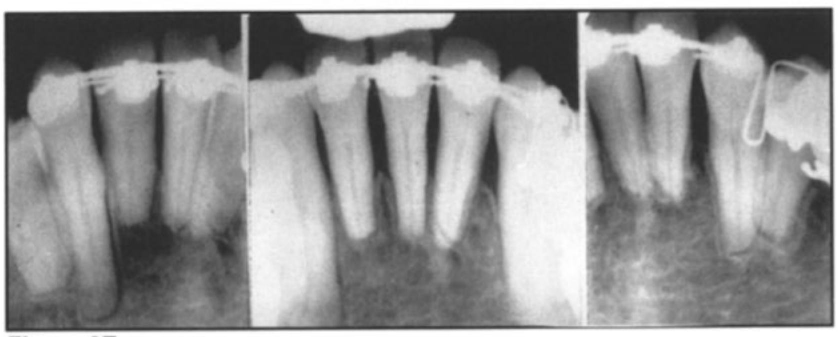

Figure 8E

Figure 8C
Posttreatment study models. The maxillary first premolars and one mandibular incisor were extracted. Note correction of the severe overjet.

Figure 8D
Periapical x-ray of the mandibular incisors taken at the ninth month of treatment. Note root resorption and bone loss.

Figure 8E
Periapical x-rays of the mandibular incisors taken one month prior to appliance removal. Note bone loss and root resorption of the mandibular incisors consistent with the perforation of the lingual cortical plate of the synthesis. The extent of the iatrogenic sequelae has stabilized since the periapicals taken at the ninth month of treatment.

(Figure 8H). The lingual wall of the synthesis displayed a bulge due to the position of the incisor roots (Figure 8I). Recession of the gingiva on the lingual of the incisors was noted.

Periapical x-rays taken just before appliance removal (Figure 8E) revealed that the mandibular incisors had lost no further bone or root length compared with x-rays taken at the ninth month of treatment and the crestal bone appeared to be denser.

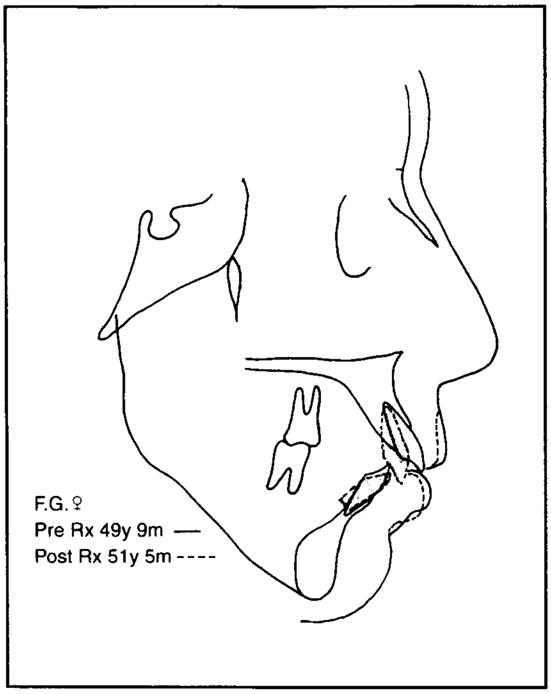

Figure 8F

Figure 8G

Figure 8H

Figure 8F
Superimposed pretreatment and posttreatment cephalometric tracings. Note thin alveolar width around the mandibular incisors at the pretreatment stage. The mandibular incisors perforated the lingual cortical plate of the synthesis during treatment and the alveolar bone did not remodel to accommodate lingual movement of the mandibular incisor roots.

Figure 8G
Detail of pretreatment cephalometric x-ray of the mandibular incisor region. Note thin alveolar housing of the mandibular incisors.

Figure 8H
Detail of posttreatment cephalometric x-ray of the mandibular incisor region. Note penetration of the synthesis and root resorption of the mandibular incisors.

Figure 8I
Posttreatment occlusal view of the mandibular incisors. Note bulge on the lingual caused by the root going beyond the lingual cortical plate of the synthesis. Also note lingual bonded retainer.

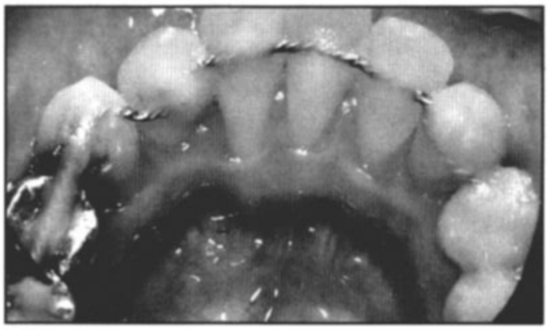

Figure 8I

The lingual root torque to the mandibular incisors was delivered inadvertently through light round wires. In most instances of extracting one mandibular incisor, the incisor roots are contained by the dense cortical plate as the crowns are aligned. The perforation and extent of apical movement in this case is highly unusual. Perhaps the combination of age and the extremely thin alveolus contributed to the perforation by the apex.

Stabilization of the affected incisors with the lingual bonded wire at the ninth month of treatment may have prevented further periodontal loss. Long-term stabilization not only prevents mobility, but will possibly allow for remodeling repair of the bone loss on the lingual of the incisors.[8] In retrospect, extraction of a mandibular incisor was a poor choice, considering the thinness of the alveolus and the extent of pre-existing bone loss.

The most common iatrogenic problems—root resorption, bone loss, and gingival recession—were seen in this patient and clearly demonstrate the association of anatomic limits dictated by the thin alveolus and the occurrence of unfavorable sequelae. Mulie and Ten Hoeve[9] illustrated what they termed incisors that "fell off the symphysis" (see their Figure 3). However, they did not report the serious iatrogenic sequelae observed in this paper. Perhaps the adolescent patients in their study were more resistant to these sequelae than the adult.

Discussion

The anatomic limits set by the cortical plates of the alveolus at the level of the incisor apices may be regarded as "orthodontic walls." Other examples of such walls are the maxillary sinus around the premolars, the inferior aspect of the palate (especially in deepbite cases), areas of sclerosed bone, and deeply imbedded fibrous frenula. It is imperative in planning treatment to consider these orthodontic walls as a limit to repositioning teeth, as well as a danger zone for heightened unfavorable sequelae.

The question remains, however: How can we determine, a priori, which borderline cases can be successfully treated by orthodontics alone without incurring unacceptable levels of bone loss and root resorption? A simple, visualized treatment objective, performed with overlay acetate papers, will determine if sufficient alveolar bone is available for safe movement of incisors to correct anteroposterior discrepancies. One should keep in mind that the cortical plates of the palate and synthesis that are traced from cephalometric x-rays present a two-dimensional view of a concave surface. The actual limit of the palate and synthesis at the midline may be narrower than the traced image.

Frequently the skeletal discrepancy is large and beyond dental compensation, i.e., outside the "envelope of discrepancy" for orthodontic treatment.[6] At times this discrepancy is small, but the thinness of the alveolar housing will not accommodate even modest movements. Orthognathic surgery is often required to improve skeletal relationships and soft tissue harmony, as well as establish a stable occlusion. There are many borderline patients who may appear to be within the range for orthodontic therapy but who, upon closer examination of their cephalometric x-rays, will require surgery because of limited alveolar width.

The mandibular incisors, more frequently than the maxillary incisors, are the cause of limitation in treatment because of the thinness of their alveolar housing.

A thin alveolus may be encountered in any skeletal type, but is most frequently encountered in patients with long lower face height and severe bimaxillary protrusion. Although only adults were studied in this paper, the observations are also applicable to individuals who are still growing, if corrective growth modification is limited.

Cephalometric x-rays were introduced by Broadbent in 1931.[14] However, no cephalometric analysis to date considers the dimensions of the incisor alveolus. A standard for the Class I average SN-MP angle group is presented (Table 4 and Figure 3) and should be incorporated in cephalometric evaluations.

A segment of the adult population, independent of orthodontic treatment, will show bone loss due to periodontal disease. Most adults undergoing orthodontic treatment will demonstrate some level of bone loss, root resorption, and gingival recession.[4-5] The causes of root resorption and bone loss are multifactorial and the architecture of the alveolar bone is only one factor. Thus, iatrogenic loss may be observed even if the apex is contained within its alveolar housing. However, the specificity and severity of the iatrogenic loss displayed in the cases reported here can best be explained by the limitations imposed by the cortical walls of the alveolus.

Kaley and Phillips[15] have shown the association between root resorption and orthodontic approximation of the maxillary incisor against the palatal cortex, and Årtun and Krogstad[13] have shown gingival recession to be correlated with thinness of the alveolus in Class III patients when mandibular incisors were proclined prior to orthognathic surgery. These papers and the clinical cases presented indicate that the limits of the anterior alveolus is an important factor in initiating iatrogenic loss.

Significant variability in iatrogenic response to orthodontic treatment is, however, seen in the presence of a thin alveolus. The cases presented were selected precisely because of the severity of the iatrogenic phenomena they demonstrated and the apparent association with a thin alveolus. A more comprehensive clinical evaluation of many patients is required to more precisely define the role of the thin alveolus. Nevertheless, patients with a thin alveolus or an alveolus inadequate to the demands of extensive tooth movement should be considered at risk for unfavorable sequelae due to orthodontic treatment. Along with rational orthodontic mechanicotherapy and maintenance of periodontal health during treatment, consideration of the anatomy of the incisor alveolus is one of the keys to minimizing unfavorable sequelae in orthodontic practice.

Conclusions

1. Cephalometric measurements were established for the various combinations of horizontal and vertical facial types for the width of bone labial and lingual to the incisor apices.

2. A narrow alveolus was frequently noted around the mandibular incisors in high SN-MP groups and in the Class III average group. A thin alveolus was often noted lingual to the maxillary incisor apex in the Class II high SN-MP group.

3. While individuals of any facial type could have a thin alveolus, this was rarely seen in low SN-MP groups or in the Class I average SN-MP group.

4. Clinical cases demonstrate that the palatal wall of the maxilla and the posterior cortex of the synthesis represent "orthodontic walls" or

barriers to tooth movement.

5. While the iatrogenic response to challenging the anatomic limits is variable, the severity of this response can compromise the periodontal support of the incisors involved.

6. Norms for alveolar width in the Class I average group are presented. A simplified prediction can be achieved using overlay acetate tracings of the projected treatment.

7. Patients with either narrow alveolar width or severe skeletal discrepancies are most likely to demonstrate limitation in orthodontic correction and may require surgery.

8. These same patients are also likely to exhibit severe iatrogenic loss of periodontal support when tooth movement challenges the "orthodontic walls" represented by the dense cortical plates at the level of the incisor apices.

9. The width of the anterior alveolus combined with a visualized treatment projection can be used in determining if the borderline patient is best treated via conventional orthodontics or a combined orthodontic-surgical program.

Acknowledgment

The author wishes to acknowledge the statistical assistance of Dr. Ellen BeGole, Department of Orthodontics, The University of Illinois at Chicago.

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This paper was first presented to the Midwest component of the Edward H. Angle Society in Tucson, Arizona, in February 1995.

Commentary

Robert M. Rubin, DMD

It was a pleasure to critique this paper. The hypothesis is clearly stated, the design of the experiment addresses the question at hand, and the sample size is large enough to test the hypothesis. The author writes with clarity and felicity. The illustrations and photographs document the findings extremely well.

The paper makes a valuable contribution to our understanding of some of the limits to orthodontic treatment. By confining the study to adults, the author avoided the complication of dealing with the influence of growth on expanding the possibilites of treatment. Perhaps that can be addressed in a future study. Also, a logical extension would be to consider the limitations of treatment in the transverse dimension. The cortical plate of the posterior maxilla and mandible are formidable barriers, and in this era of nonextraction and expansion, it is helpful to explore the physical limitations that must be faced.

References

1. Proffit WR, White RP Jr. Who needs surgical-orthodontic treatment? Int J Adult Orthod Orthognath Surg 1990;5:81-89.
2. Proffit WR, Phillips C, Douvartzidis A. Comparison of orthodontic and surgical-orthodontic treatment of Class II malocclusion in adults. Am J Orthod Dentofac Orthop 1992;101:556-565.
3. Cassidy DW Jr., Herbosa EG, Rotskoff KS, Johnston LE, Jr. A comparison of surgery and orthodontics in "borderline" adults with Class II, Division 1 malocclusions. Am J Orthod Dentofac Orthop 1993;104:455-470.
4. Lupi JE, Handelman CS , Sadowsky C. Prevalence and severity of apical root resorption and alveolar bone loss in orthodontically treated adults. Am J Orthod Dentofac Orthop: In press.
5. Handelman, C.S. Limitations of orthodontic treatment in adults: Part I, The impact of iatrogenic phenomena. In: McNamara JA Jr., Trotman CA, eds. Orthodontic treatment: The management of unfavorable sequalae. Monograph 32, Craniofacial Growth Series, Center for Human Growth and Development. Ann Arbor:The University of Michigan, 1996;177-203.
6. Proffitt WR , Ackerman JL. Diagnosis and treatment planning. In: Graber TM, Swain BF, eds. Current orthodontic concepts and techniques. St. Louis: Mosby, 1982, chapter 1.
7. Edwards JG. A study of the anterior portion of the palate as it relates to orthodontic therapy. Am J Orthod 1976; 69:249-273.
8. Ten Hoeve A, Mulie RM. The effect of anterio-posterior incisor repositioning on the palatal cortex as studied with laminography. J Clin Orthod 1976; 10:804-22.
9. Mulie RM, Ten Hoeve A. The limitations of tooth movement within the symphysis studied with laminography and standardized occlusal films. J Clin Orthod 1976; 10: 882-93.
10. Sassouni V. A classification of skeletal facial types. Am J Orthod 1969; 55:109-123.
11. Isaacson JR, Issacson RJ, Speidel TM, Worms FW. Extreme variation in vertical facial growth and associated variation in skeletal and dental relations. Angle Orthod 1971;41:219-229.
12. Sperry TP, Speidel TM, Isaacson RJ, Worms FW. The role of dental compensations in orthodontic treatment of mandibular prognathism. Angle Orthod 1977; 47:293-299.
13. Årtun J, Krogstad O. Periodontal status of mandibular incisors following excessive proclinations. A study in adults with surgically treated mandibular prognathism. Angle Orthod 1987; 47:293-299.
14. Broadbent BH. A new x-ray technique and its application to orthodontia. Angle Orthod 1931; 1:45-66.
15. Kaley J, Phillips C. Factors related to root resorption in edgewise practice. Angle Orthod 1991; 61:125-132.