



Class III surgical-orthodontic treatment: A cephalometric study

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Introduction: In this retrospective study, we investigated treatment outcomes in Class III surgical-orthodontic patients. **Methods:** Records of 151 consecutively completed Class III surgical-orthodontic patients (overjet, 0 mm or less) were obtained from 87 consultant orthodontists in the United Kingdom. Pretreatment and posttreatment cephalometric radiographs were analyzed. **Results:** Bimaxillary surgical patients (75%) had more negative initial ANB-angle values and smaller initial SNA-angle values than those treated with single-jaw mandibular surgery. Mandibular surgery patients (15%) had greater pretreatment mandibular prominence (SNB angle) than maxillary patients. Maxilla-only patients (10%) had lower negative initial overjet values than bimaxillary patients. An overjet within the ideal range of 1 to 4 mm was achieved in 83% of the patients. Logistic regression identified no predictors of ideal overjet outcome. SNB angle was corrected to within the ideal range of 75° to 81° in 44% of the patients. This was less likely in those treated with maxillary surgery only and larger initial SNB-angle values. An ideal posttreatment ANB angle (1° to 5°) was achieved in 40% of the patients and was more likely in those with bimaxillary surgery, lower negative pretreatment ANB angles, and presurgical orthodontic extractions in the maxillary arch. Ideal posttreatment unadjusted Holdaway angles (7° to 14°) were achieved in 59% of the patients and were more likely when single-jaw mandibular surgery was used. Incisor decompensation was incomplete in 46% of the patients and was associated with mandibular arch extractions. **Conclusions:** Surgical-orthodontic treatment had a high success rate in normalizing the overjet and soft-tissue profile to within ideal ranges in Class III patients. Bimaxillary surgery was the most frequently used procedure and was associated with an increased likelihood of an ideal correction of the anteroposterior skeletal discrepancy. (*Am J Orthod Dentofacial Orthop* 2006;130:300-9)

Approximately 4% of the population has a dento-facial deformity that requires surgical-orthodontic treatment to correct; the most common indications for surgical treatment are severe Class II, Class III, and vertical skeletal discrepancies in non-growing patients.¹ Class III patients are a large proportion of those seeking surgical-orthodontic treatment. Proffit et al² reported that 20% of patients at a surgical-orthodontic clinic had mandibular excesses, with 17% having maxillary deficiencies and 10% having both. A subsequent article from the same center reported that

patients with Class III problems were more likely to seek clinical evaluation than Class II patients.³

Most people with Class III malocclusions have dentoalveolar and skeletal problems,⁴ and mild cases can often be treated with orthodontics only. However, patients with significant Class III skeletal discrepancies are often treated with mandibular, maxillary, or bimaxillary orthognathic surgery in conjunction with orthodontic appliance treatment. Few studies have examined the factors that influence the choice between conventional orthodontic treatment and surgical-orthodontic treatment. Kerr et al⁵ reported that patients with ANB angles of less than -4° and mandibular incisor inclinations of less than 83° were more likely to have surgical-orthodontic treatment than conventional orthodontic treatment. A more recent study concluded that surgical patients could be distinguished from nonsurgical ones on the basis of Wits measurement, maxillary/mandibular length ratio, gonial angle, and sella-nasion distance.⁶

The main objectives of surgical-orthodontic treatment are to normalize the facial profile, occlusion, and function. Correction of the main dentoskeletal parameters to within the normal range of values is usually regarded as a main aim of treatment. In practice, the

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choice among the various surgical procedures is based on clinical examination and cephalometric evaluation. Surprisingly, however, little research examines which cephalometric factors influence treatment planning.

In this study, we investigated the cephalometric outcomes of a large sample of Class III surgical-orthodontic patients. It was part of a larger retrospective, multi-center study in the United Kingdom (UK) to examine the provision and outcome of surgical-orthodontic treatment in the hospital consultant orthodontic service.

Our aims were to (1) investigate the treatment outcome of Class III surgical-orthodontic patients, (2) identify predictors of the best cephalometric outcomes, and (3) identify the cephalometric factors that influenced the choice of surgical procedure.

SUBJECTS AND METHODS

Each UK consultant orthodontist providing surgical-orthodontic treatment ($n = 160$) was asked to provide pretreatment and posttreatment cephalometric radiographs of 6 consecutively completed surgical-orthodontic patients who had surgery before September 1998. One hundred ten consultants provided cephalometric records. The orthodontists were asked to supply additional demographic and surgical data about each patient (Table I). Class III patients were identified by using the definition of a pretreatment overjet of 0 mm or less. Patients with cleft lips and palates and those with craniofacial syndromes were excluded. Subjects were included only if their pretreatment cephalometric radiographs had been recorded at minimum ages of 15 years for girls and 17 years for boys.

The pretreatment and posttreatment cephalometric radiographs for each patient were digitized with the Opal Image orthognathic planning software (Version 1.3, COGSOFT, British Orthodontic Society, London, UK) on a computer with a digitizing screen (Numonics digitizing screen, SSi Microcad, Pewsey, UK) with an accuracy of 0.1 mm. The precision of this digitizer was evaluated previously and found to have excellent accuracy.⁷

All linear measurements were corrected for magnification. If a magnification scale was not on a cephalometric film, the participating consultant was instructed to record a cephalometric radiograph of a standardized 15-cm rod that had been specifically engineered to allow calculation of the magnification factor of each cephalostat (Dontaur Engineering, Ballymena, Northern Ireland). The rods were produced with notches at 5 and 10 cm and with a specification of less than 0.1-mm error in length. If a different cephalostat had been used for a patient's pretreatment and posttreatment cephalometric radiographs, the difference in length between

Table I. Patient and treatment data collected for each patient

Variable
Patient's sex
Age at start of treatment
Duration of presurgical and postsurgical orthodontic phases
Whether maxillary arch extractions (excluding third molars) were carried out
Whether mandibular arch extractions (excluding third molars) were carried out
Whether previous orthodontic treatment had been carried out
Whether orthodontic extractions had been carried out in previous treatment.
Whether rigid internal fixation (plating) was used
Type of surgical procedure (mandible only, maxilla only, or bimaxillary)
Whether genioplasty procedure was also carried out
Average number of surgical-orthodontic patients treated by surgeon per year

sella-nasion of the 2 radiographs was used to determine whether the magnification had altered; if so, the values of any linear measurements were adjusted accordingly. Sella-nasion is considered to be relatively stable after 7 years of age.

The cephalometric variables that were measured are shown in Table II and Figure 1. The maxillary plane was defined as posterior nasal spine to anterior nasal spine, and mandibular plane was defined as gonion to menton. Holdaway angle was defined as the angle of soft-tissue nasion to soft-tissue pogonion to labrale superius (Fig 1). A horizontal reference line was constructed by rotating the sella-nasion line downward by 6° , and a vertical reference line was constructed perpendicularly through sella. The horizontal and vertical movements of Points A and B relative to these lines were used to describe the surgical movements of the maxilla and mandible, respectively.

The error of the method was assessed by using replicated tracings and measurements of 30 randomly selected films, with the method error values calculated by using the formula described by Dahlberg⁸: $Se = \sqrt{(\sum d^2/2n)}$, where Se is the method error (or standard deviation of the difference of each of the paired measurements from its own pair mean), d is the difference between the first and second recordings, and n is the number of radiographs replicated.

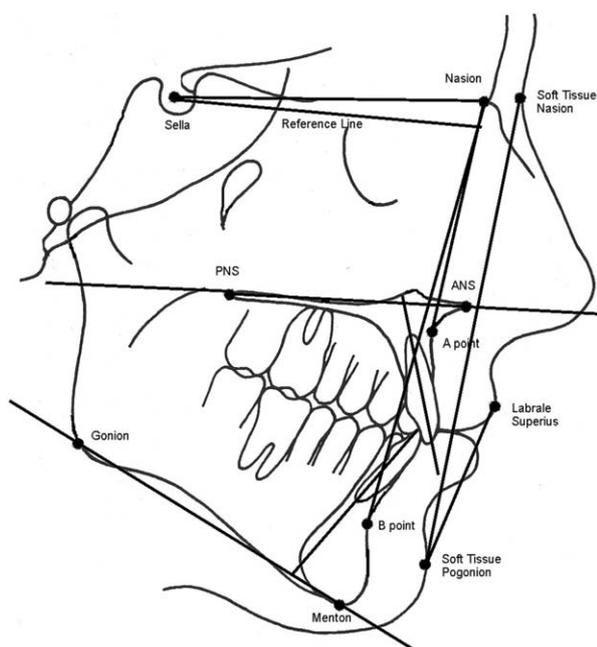
In addition, paired t tests were used to detect any systematic differences between the original and replicated measurements.⁹

Statistical analysis

Paired samples t tests were used to compare the pretreatment and posttreatment cephalometric values

Table II. Cephalometric measurements and ideal ranges

Variable	Definition	Ideal range
SNA angle (°)	Maxillary prominence (sella-nasion-A-point)	78-84
SNB angle (°)	Mandibular prominence (sella-nasion-B-point)	75-81
ANB angle (°)	Skeletal AP relationship	1-5
Mx:Mn (°)	Maxillary-mandibular plane angle	23-31
LFH% (N-Me)/ (Ans-Me) (%)	Mandibular anterior facial proportion	53-57
Overjet (mm)	Overjet	1-4
Overbite (mm)	Overbite	1-4
UI:Mx (°)	Maxillary incisor inclination (relative to maxillary plane)	103-115
LI:Mn (°)	Mandibular incisor inclination (relative to mandibular plane)	87-99
Holdaway angle (°)	Soft-tissue AP relationship	7-14

**Fig 1.** Landmarks and lines used in cephalometric analysis.

for each patient. Analysis of variance (ANOVA) and Duncan post hoc tests were used to compare the pretreatment cephalometric values between groups of patients treated with bimaxillary, mandibular, and maxillary surgical procedures.

For each pretreatment and posttreatment cephalometric variable, the percentage of patients in the ideal range was identified (Table II). For skeletal and dentoskeletal measurements, the ideal ranges were based

on the Eastman normal values,¹⁰ with the ideal range defined as within 1 SD of the normal mean. The ideal range of 7° to 14° for the soft-tissue Holdaway angle was based on the recommendation of its originator,¹¹ and the ideal ranges of 1 to 4 mm for overjet and overbite were those recommended by Profitt et al.¹² Many logistic regression analyses were carried out to identify predictors of achieving ideal outcomes for the 2 key skeletal measurements (ANB and SNB angles), the key dental measurement (overjet), and the key soft-tissue measurement (Holdaway angle). The independent variables entered into the regression analyses included 21 pretreatment cephalometric, patient, and treatment factors (Tables I and II).

RESULTS

By using the study inclusion criteria, 151 Class III patients were identified from a total sample of 620 consecutive surgical-orthodontic patients from the consultant orthodontists. These patients were treated by 87 consultant orthodontists, and 73% of the patients were female. The pretreatment cephalometric radiographs were recorded for the female patients at a mean age 21.7 years (range, 15.0-51.4 years) and for the male patients at a mean age of 21.9 years (range, 17.1-41.5 years). The posttreatment cephalometric radiographs had been recorded at an average of 10 months after surgery (range, 0-51 months). Posttreatment cephalometric radiographs were recorded less than a year after surgery in 71% of the patients, and more than 2 years after surgery in 12%.

Twenty-seven percent of the patients had previous orthodontic treatment before the presurgical orthodontic treatment; 42% of the Class III patients had anterior open bites (overbite less than 0 mm) at the start of treatment.

The method error values varied between 0.43° and 1.56°. Only UI:Mx (1.56°) and LI:Mn (1.44°) were greater than 1°. There was evidence of some systematic error with the measurement of LFH% ($P = .02$), although the method error for this measurement was small at 0.84% (see Table II for definitions).

Bimaxillary surgery was used for 75% of the patients. Single-jaw maxillary surgery and mandibular surgery were used in 10% and 15%, respectively. The sizes of the surgical movements are reported in Table III.

ANOVA among the surgical groups for the pretreatment cephalometric measurements is reported in Table IV. Bimaxillary patients had significantly more negative pretreatment mean ANB-angle values and smaller mean SNA-angle values than those treated with single-jaw mandibular surgery. The size of the mean reverse overjet was larger in the bimaxillary patients

Table III. Skeletal movements for Points A and B for single-jaw maxillary and mandibular procedures and bimaxillary procedures

Movement	Type of surgery	Mean (mm)	SD (mm)	Minimum (mm)	Maximum (mm)
Horizontal Point A	Maxilla	4.3	2.1	-0.4	7.4
	Mandible	-0.5	1.8	-4.2	3.2
	Bimaxillary	4.3	3.1	-2.9	13.8
Vertical Point A	Maxilla	-1.6	3.1	-6.2	4.1
	Mandible	-0.2	1.5	-4.1	2.1
	Bimaxillary	0.0	2.8	8.1	10.7
Horizontal Point B	Maxilla	-0.3	3.4	-6.6	4.5
	Mandible	-6.8	4.4	-13.5	3.7
	Bimaxillary	-4.4	5.2	-20.0	7.9
Vertical Point B	Maxilla	-0.3	3.7	-7.4	4.3
	Mandible	0.0	3.5	-5.5	6.8
	Bimaxillary	2.4	4.3	-14.1	11.9

Upward and forward movements indicated by positive values.

than in the maxillary patients. Maxillary patients had significantly lower mean SNA and SNB angle values than mandibular patients. Mandibular patients had greater mean SNA angulations than the maxillary and bimaxillary patients.

Maxillary arch extractions were carried out in 27% of the patients and mandibular arch extractions in 9%.

The pretreatment and posttreatment cephalometric data for the whole sample are summarized in Table V and Figures 2 to 11. The skeletal parameters SNA, SNB, and ANB angles showed significant improvements toward ideal values. The mean changes in the vertical skeletal dimensions were small and nonsignificant (maxillary-mandibular plane angle and lower facial proportions). The mean overjet and maxillary and mandibular incisor inclinations increased significantly as a result of treatment. Soft-tissue analysis showed an overall significant improvement in the unadjusted Holdaway angle.

The pretreatment parameters most frequently outside the ideal ranges were overjet, ANB and SNB angles, and mandibular incisor inclination. Pretreatment maxillary incisor inclination (Fig 9) was the least frequent measurement outside the ideal range (41%).

Overall, overjet correction was successful, with 83% of the patients having ideal posttreatment overjets, and only 5% still having overjets of less than 1 mm at the end of treatment (Fig 7).

Skeletal correction was not as successful as overjet correction, with 40% of the patients having ideal ANB angles at the end of treatment (Fig 4); 54% had final ANB angles below the ideal range, and 52% still had excessive SNB angles at the end of treatment (Fig 3). There was evidence of incomplete incisor decompen-

sation, with 46% having posttreatment mandibular incisor inclinations of less than 87° (more than 1 SD below the Eastman normal value), and 33% having proclined maxillary incisors (more than 115°) at the end of treatment (Figs 9 and 10). The posttreatment unadjusted Holdaway angle was in the ideal range in 59% of the patients (Fig 11).

Because the posttreatment cephalometric radiographs had been recorded at various times after surgery, the cephalometric outcomes were further analyzed by comparing posttreatment films recorded a year or less after surgery (71%) with those recorded more than a year after surgery (29%). The mean posttreatment overjet and maxillary incisor inclination were statistically significantly smaller for the group with later cephalometric films, but the differences were modest (2.5° for incisor inclination and 0.45 mm for overjet) (Table VI).

Predictors of outcomes

Due to the many independent variables entered into the regression analyses, only factors reaching statistical significance ($P < .05$) are reported in Tables VII and VIII. Logistic regression showed that an ideal ANB-angle outcome was associated with bimaxillary surgery, less negative pretreatment ANB angle, and maxillary arch extractions. The odds of achieving an ideal SNB-angle outcome were reduced as the initial angle increased and when single-jaw maxillary surgery was used. The odds of an ideal Holdaway angle at the end of treatment were increased in patients treated with single-jaw mandibular surgery. No factors associated with ideal overjet outcome were identified.

Because the mandibular incisors were still retroclined below the normal range at the end of treatment in 46% of the patients, a further logistic regression analysis was performed to identify possible explanations. Incomplete decompensation (posttreatment mandibular incisor inclination $< 87^\circ$) was associated with mandibular arch extractions during the presurgical orthodontic phase, fewer completed patients by the orthodontist per year, and the following pretreatment cephalometric factors: larger SNA angle, larger reverse overjet, and more retroclined mandibular incisors. The maxillary incisors remained compensated (inclination $> 115^\circ$) in 33% of the patients. Logistic regression showed that this was more likely with greater pretreatment maxillary incisor proclination and in patients treated with maxillary advancement only.

DISCUSSION

We examined a large consecutive sample of surgically treated Class III malocclusions; the study was

Table IV. Pretreatment ANOVA by surgical procedure

	Maxilla only (n = 15)		Mandible only (n = 22)		Bimaxillary (n = 114)	
	Mean	SD	Mean	SD	Mean	SD
SNA angle (°)	78.1 *Mn	4.4	81.4 *Mx*Bi	4.8	77.5 *Mn	4.6
SNB angle (°)	83.1 *Mn	4.1	85.7 *Mx	4.0	84.0	4.4
ANB angle (°)	-5.0	2.9	-4.3 *Bi	2.6	-6.5 *Mn	3.6
Mx:Mn angle (°)	24.5	9.7	27.0	5.8	28.0	7.7
LFH (%)	56.8	3.2	57.5	2.2	57.9	2.8
Overjet (mm)	-2.3 *Bi	1.3	-2.7	1.6	-4.1 *Mx	2.9
Overbite (mm)	0.6	3.4	0.3	2.6	0.3	3.2
Max incisor (°)	111.8	8.5	112.7	7.2	111.5	6.5
Mand incisor (°)	84.9	9.3	83.2	6.5	81.8	10.2
Holdaway (°)	3.2	5.8	1.5	6.9	0.9	5.9

Mx, Maxilla only; Mn, mandible only; Bi, bimaxillary surgery; Max, maxillary; Mand, mandibular.

*Significant difference with another surgical group ($P < .05$).

Table V. Pretreatment and posttreatment cephalometric data

	Pre treatment		Post treatment		Change		95% CI		P
	Mean	SD	Mean	SD	Mean	SE	Lower	Upper	
SNA angle (°)	78.12	4.77	81.78	4.59	3.66	0.29	3.09	4.23	0.00
SNB angle (°)	84.16	4.31	81.11	3.93	-3.05	0.25	-3.53	-2.56	0.00
ANB angle (°)	-6.03	3.49	0.67	3.01	6.70	0.25	6.21	7.19	0.00
Mx:Mn angle (°)	27.49	7.69	28.12	6.06	0.63	0.54	-0.43	1.69	0.24
LFH (%)	57.71	2.73	57.52	2.11	-0.19	0.17	-0.52	0.14	0.26
Overjet (mm)	-3.74	2.73	2.72	1.20	6.46	0.24	5.98	6.94	0.00
Overbite (mm)	0.37	3.14	0.91	1.37	0.54	0.26	0.02	1.06	0.04
Max incisor inclination (°)	111.71	6.81	112.52	6.54	0.80	0.50	-0.18	1.78	0.11
Mand incisor inclination (°)	82.28	9.68	87.27	7.06	4.99	0.67	3.66	6.32	0.00
Holdaway (°)	1.19	6.04	9.92	5.72	8.74	0.54	7.66	9.81	0.00

Max, maxillary; Mn, mandible only; Mand, mandibular or mandible.

primarily designed as a cephalometric investigation. Therefore, we did not assess intra-arch alignment, buccal segment occlusal relationships, patient satisfaction, or sensory deficit that might have occurred as a result of surgical nerve trauma. Posteror anterior (PA) views of the skull were not analyzed because this has not gained wide acceptance in the UK,¹² and there are no widely accepted methods of PA cephalometric analysis. Nevertheless, the cephalometric data give invaluable insight into the types of Class III cases currently being treated surgically in the UK, where hospital consultant orthodontists and surgeons carry out almost all surgical-orthodontic treatment.

Ongoing facial growth is a potential confounding variable in studies of orthodontic treatment outcome. In this study, only patients with initial cephalometric radiographs recorded at minimum ages of 15 years for girls and 17 years for boys were included in the sample. By these ages, it is generally accepted that the circumpubertal growth is complete or almost complete,¹³ and thus the possible effects of facial growth in our

sample were minimized. Although some late mandibular growth can occur up to 20 years of age, a survey of more than 300 orthodontists reported that the recommended earliest ages for orthognathic surgery were 14.9 years for girls and 16.5 years for boys.¹⁴ The choice of the minimum ages in our study is further supported by the finding that patient age at the start of treatment was not identified in the regression analyses as associated with treatment outcome.

A strength of this study was the inclusion of consecutive patients from each unit, regardless of outcome. This approach gave a realistic view of regular clinical practice, but the patients reflect variations in record-taking protocols. In this instance, the posttreatment cephalometric films from the orthodontists were recorded at various times after surgery. Ideally, all posttreatment films should be recorded after a standard interval, but this was not possible with this retrospective multi-center study, which showed wide variations in posttreatment radiographic protocols. Only overjet and maxillary incisor inclination differed significantly

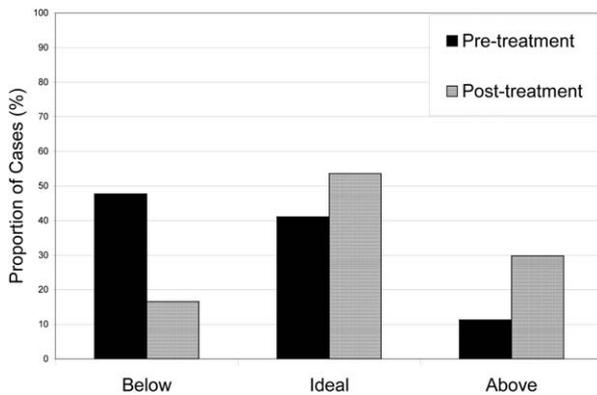


Fig 2. Treatment efficacy: percentages of patients before and after treatment with SNA angles below, within, and above ideal range.

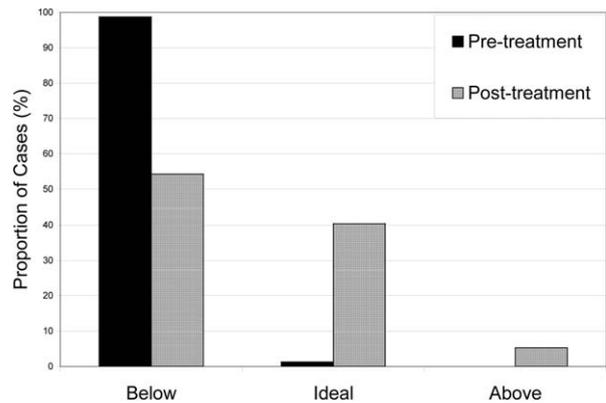


Fig 4. Treatment efficacy: percentages of patients before and after treatment with ANB angles below, within, and above ideal range.

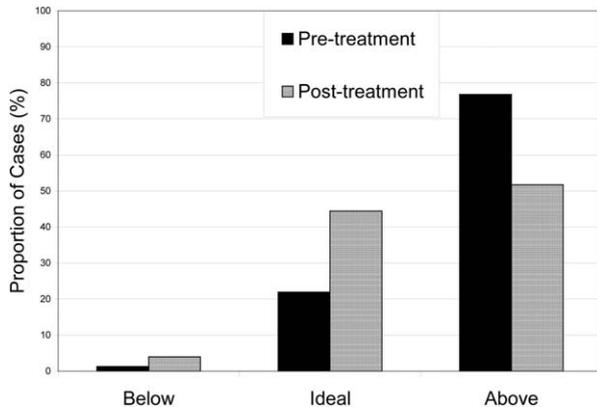


Fig 3. Treatment efficacy: percentages of patients before and after treatment with SNB angles below, within, and above ideal range.

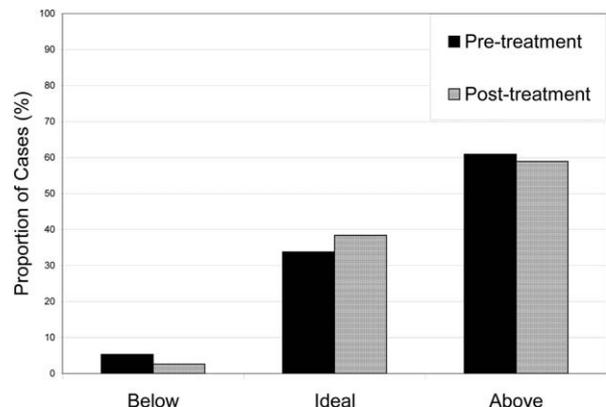


Fig 5. Treatment efficacy: percentages of patients before and after treatment with LFH proportions below, within, and above ideal range.

between patients, with postoperative cephalometric films recorded up to a year after surgery and those recorded more than a year after surgery. However, these differences were extremely small, although the smaller overjet in the later cephalometric group could be interpreted as evidence of mild relapse in the posttreatment incisor relationship.

The aim of surgical-orthodontic treatment is to normalize the main skeletal and dental relationships, and cephalometric analysis allows scientific analysis of these relationships. We used a similar cephalometric method of assessing treatment efficacy to that in a previous study of Class II surgical-orthodontic subjects.¹⁵ Those authors proposed that the efficacy of treatment should be assessed on the basis of whether the treatment goals of acceptable skeletal and soft-tissue proportions, normal occlusion, and acceptable

dentofacial esthetics were achieved. This was reported as the proportion of patients whose various posttreatment cephalometric and occlusal measurements fell within predefined ideal or acceptable ranges.

The cephalometric measurements that we analyzed were chosen to concisely describe the main skeletal, dental, and soft-tissue changes after treatment. The study sample was defined on the basis of a pretreatment overjet of 0 mm or less. Overjet correction resulting from treatment was successful, with less than 5% of the patients having overjets of less than 1 mm at the end of treatment. In their sample of Class II surgical patients, Proffit's group similarly reported that overjet was successfully corrected to the normal range in 95% of patients.¹⁵ The lack of predictive factors in our study for successful overjet reduction is perhaps unsurprising in view of the high success rate in achieving an ideal overjet.

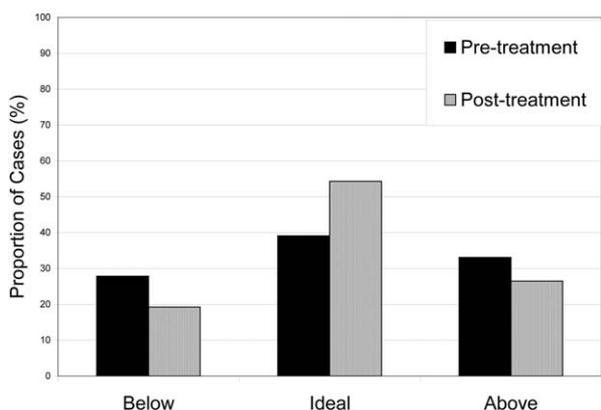


Fig 6. Treatment efficacy: percentages of patients before and after treatment with maxillary-mandibular plane angles below, within, and above ideal range.

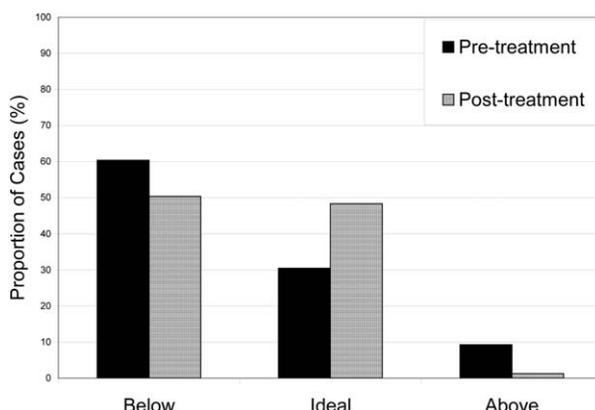


Fig 8. Treatment efficacy: percentages of patients before and after treatment with overbites below, within, and above ideal range.

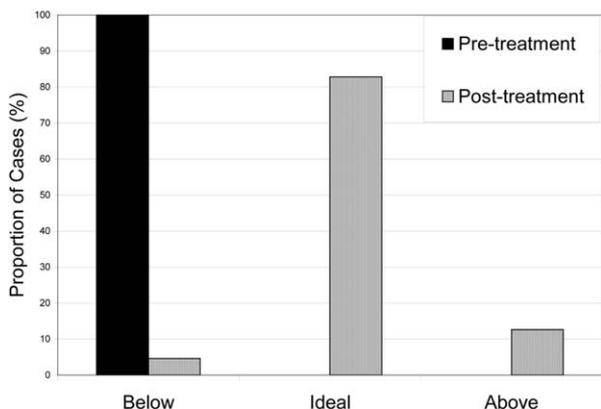


Fig 7. Treatment efficacy: percentages of patients before and after treatment with overjets below, within, and above ideal range.

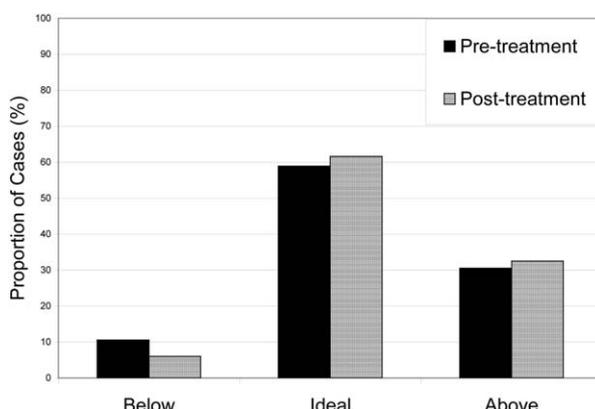


Fig 9. Treatment efficacy: percentages of patients before and after treatment with maxillary incisor inclinations below, within, and above ideal range.

In our sample, correction of the AP skeletal relationships was less successful than overjet correction; 54% of the patients still had ANB angles of less than 1° at the end of treatment, and 52% had SNB angles of more than 81° at the end of treatment. A main aim of the presurgical orthodontic phase is to correct the incisor inclinations to normal to allow maximum surgical correction,¹⁶ and the less-than-ideal outcomes for the skeletal relationships might have been due to inadequate presurgical orthodontic decompensation of the incisor inclinations. Almost half of the patients had retroclined mandibular incisors at the end of treatment (less than 87°); this would have restricted the full correction of the skeletal relationships. Incomplete presurgical decompensation of the mandibular incisors has several possible causes, including inadequate labial bone to allow sufficient advancement of the mandibular

incisors, previous mandibular arch extractions, lower lip muscle resistance to mandibular incisor advancement, and poor patient compliance with intraoral Class II elastic traction. In this study, incomplete mandibular incisor decompensation was more than 4 times more likely when mandibular extractions were carried out during the presurgical orthodontic phase. Other factors associated with incomplete mandibular incisor decompensation included the severity of the pretreatment retroclination of the mandibular incisors and the size of the initial reverse overjet. There was also evidence of similar problems in the maxillary arch, with a third of the patients still exhibiting significant compensatory proclination (115° or greater) of the maxillary incisors at the end of treatment. Patients with greater pretreatment maxillary incisor proclinations and those treated with maxillary advancement only were more likely to

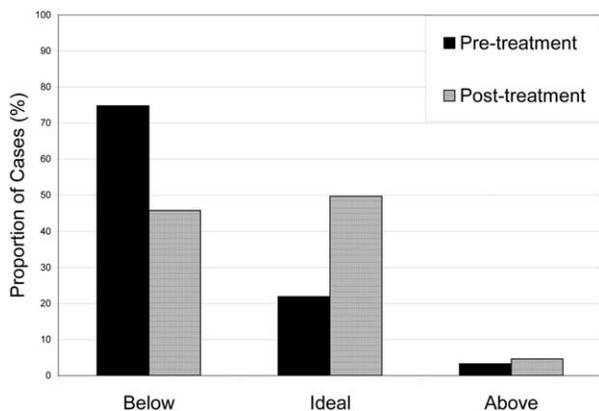


Fig 10. Treatment efficacy: percentages of patients before and after treatment with mandibular incisor inclinations below, within, and above ideal range.

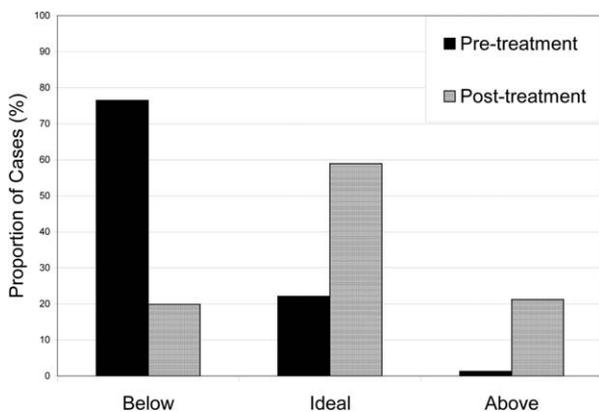


Fig 11. Treatment efficacy: percentages of patients before and after treatment with Holdaway angles below, within, and above ideal range.

have compensated proclined maxillary incisors at the end of treatment. Furthermore, ideal correction of the ANB angle was more likely if maxillary premolars were extracted during the presurgical orthodontic phase. The other factors that can limit presurgical decompensation were reported by Edler,¹⁷ particularly the restrictions imposed by previous extractions and orthodontic treatment. In our study, the previous histories of orthodontic treatment and extractions (before presurgical orthodontics) were entered into the regression analyses, although no factor was associated with treatment outcome. The finding that orthodontists who treat fewer surgical patients per year were more likely to incompletely decompensate the mandibular incisors is interesting, although, unexpectedly, the duration of the presurgical orthodontic phase was not related to decompensation of maxillary or mandibu-

lar incisors. It therefore does not seem advantageous to spend more time in the presurgical orthodontic phase of treatment.

Despite the observed problems with achieving adequate decompensation, the results nevertheless show that surgical treatment almost always fully corrected the overjet. Because surgeons aim to produce occlusions with normal overjets when repositioning the maxilla or the mandible during surgery, the desired normal overjet can usually be achieved surgically, regardless of the standard of orthodontic decompensation or arch alignment. Furthermore, when surgery does not fully correct the overjet, the postoperative orthodontic phase is a further opportunity to fully correct it by using intermaxillary elastic traction or orthodontic retraction of the mandibular incisors with any available mandibular arch spacing.

Although the efficacy of ANB-angle correction can be seen as less satisfactory, the evaluation of the soft-tissue profile by using the unadjusted Holdaway angle showed that most patients were finished with soft-tissue profiles within Holdaway's recommended range and that this was more likely with single-jaw mandibular surgery. Only 20% of the patients still had Class III soft-tissue profiles (Holdaway values below the ideal range) at the end of treatment. Although the posttreatment Holdaway angles indicated Class II profiles in 21% of the patients, this is unlikely to be a major concern to most patients because even a moderate mandibular profile deficiency is often regarded as acceptable.¹⁸ The external facial profile balance, as assessed by the unadjusted Holdaway angle, was therefore corrected more successfully than the underlying skeletal relationship. However, it is recognized that subjective patient and clinician perceptions of soft-tissue profiles would also be important, and it was not possible to fully assess these aspects in this study.

The directions and sizes of the surgical movements reported in Table III were measured as changes in the horizontal and vertical positions of Points A and B. Some changes might be partially due to orthodontic tooth movement affecting the position of these alveolar points. Despite the minimum age restrictions in the sample, some late residual facial growth might also have contributed to the skeletal and dentoalveolar changes. A few patients had atypical horizontal movements of skeletal points (ie, some had forward movement of Point B or backward movement of Point A). Further examination of these outliers confirmed that the overall relative movements of both jaws were almost always in the expected direction. Thus, if Point B

Table VI. Comparison of posttreatment measurements of patients with cephalometric films recorded up to 1 year after surgery and those with films recorded more than a year after surgery

	Posttreatment ceph ≤1 year after surgery		Posttreatment ceph >1 year after surgery		Difference		95% CI		P
	Mean	SD	Mean	SD	Mean	SE	Lower	Upper	
SNA angle (°)	81.68	4.47	82.04	4.90	0.36	0.82	-1.99	1.26	.66
SNB angle (°)	81.17	4.09	80.97	3.57	-0.20	0.71	-1.20	1.59	.78
ANB angle (°)	0.50	2.90	1.06	3.24	0.56	0.54	-1.63	0.50	.30
Mx:Mn angle (°)	27.62	5.94	29.34	6.25	1.72	1.08	-3.85	0.42	.11
LFH (%)	57.45	2.20	57.68	1.90	0.22	0.38	-0.97	0.53	.56
Overjet (mm)	2.85	1.13	2.40	1.32	-0.44	0.21	0.03	0.86	.04
Overbite (mm)	0.91	1.22	0.89	1.70	-0.02	0.25	-0.46	0.51	.93
Max incisor inclination (°)	113.23	6.83	110.78	5.46	-2.45	1.16	0.16	4.74	.04
Mand incisor inclination (°)	87.53	6.93	86.65	7.43	-0.87	1.27	-1.63	3.37	.49
Holdaway (°)	10.11	6.12	9.40	4.51	-0.70	1.02	-1.31	2.72	.49

Max, maxillary; Mand, mandibular; ceph, cephalometric film.

Table VII. Logistic regression analyses for ideal outcomes

	B	SE	Wald	Odds ratio	P
Ideal outcome for ANB angle					
Bimaxillary surgery	1.21	0.48	6.41	3.37	.01
Max arch extractions	0.48	0.22	4.81	1.62	.03
Initial ANB angle	0.31	0.07	18.45	1.37	.03
Constant	0.25	0.48	0.27		
Ideal outcome for SNB angle					
Initial SNB angle	-0.24	0.05	19.44	0.79	.00
Max surgery only	-3.05	1.12	7.40	0.05	.01
Constant	20.10	4.59	19.21		
Ideal outcome for Holdaway angle					
Mand surgery only	1.21	0.59	4.26	3.35	.04
Constant	0.24	0.19	1.65		

Max, maxillary; Mand, mandibular; B, coefficient; Wald, Wald statistic.

moved forward, then Point A moved at least as far forward and vice versa.

A single-jaw mandibular setback procedure was used in only 15% of the patients in the sample. This is consistent with reports from North American samples, in which fewer than 10% of patients during the 1990s had single-jaw mandibular surgery.¹⁹ The pretreatment values for the SNA and SNB angles in Table IV suggest that these cephalometric values influenced the choice of surgery in a logical manner. Patients selected for treatment with bimaxillary surgery had larger ANB-angle discrepancies, and single-jaw mandibular surgery was used with more normal pretreatment SNA-angle

Table VIII. Logistic regression analysis for incisors still being compensated at end of treatment

	B	SE	Wald	Odds/ratio	P
Mand incisors					
Presurgical mand extractions					
Initial SNA angle	1.43	0.73	3.80	4.18	.05
Initial overjet	0.10	0.04	5.16	1.10	.02
Initial mand incisor inclination	-0.19	0.08	6.01	0.83	.01
Patients treated by orthodontist per year					
Initial mand incisor inclination	-0.12	0.03	16.42	0.89	.00
Constant	-0.04	0.02	4.23	0.96	.04
Max incisors					
Initial max incisor inclination	1.73	3.64	0.23		
Max surgery only	0.18	0.04	20.99	1.20	.00
Constant	1.80	0.72	6.29	6.04	.01
Constant	-21.31	4.48	22.65		

Max, maxillary; Mand, mandibular; B, coefficient; Wald, Wald statistic.

values. There has been an increase in the use of bimaxillary surgery during the last 2 decades because it is increasingly recognized to produce more stable results than single-jaw mandibular procedures in Class III correction. In a recent study, it was concluded that bimaxillary surgery was more stable beyond 2 years postoperatively than single-jaw surgery.²⁰ Our study further supports the use of bimaxillary surgery in Class III discrepancies from a treatment-outcome perspective. Logistic regression showed that the odds of bimaxillary surgery achieving an ideal posttreatment ANB angle were 3.4 times greater than for single-jaw surgery, even though the average pretreatment ANB-angle discrepancy was larger in bimaxillary patients than in mandibular-only patients.

CONCLUSIONS

Surgical-orthodontic treatment was extremely successful in correcting overjet to the ideal range in these Class III patients. Although AP skeletal correction (ANB angle) was less successful than overjet correction, most patients finished with soft-tissue profiles within the normal range. Bimaxillary surgery was used in 75% of the patients, and these had more severe skeletal and dental discrepancies than those treated with single-jaw procedures. However, bimaxillary surgery had 3.4 times the odds of fully correcting the ANB angulations than single-jaw surgery. Clinicians should be aware of the potential limitation of incomplete maxillary and mandibular incisor decompensation on skeletal outcomes. Particular attention should be paid to patients with mandibular arch extractions and those with retroclined mandibular incisors or proclined maxillary incisors at the start of treatment.

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