A study of Class III treatment: orthodontic camouflage vs orthognathic surgery

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Aim: To evaluate the differences in pretreatment and post-treatment characteristics of Class III patients treated with orthodontic camouflage or orthognathic surgery, and to compare the range of skeletal, dental and soft tissue changes that are likely to occur with treatment, with particular reference to the influence of extractions on the resultant incisor angulations.

Method: Pretreatment and post-treatment cephalograms of 31 Class III orthodontically-camouflaged patients and 36 Class III surgical patients (without genioplasty) were obtained from one specialist practice. From the surgical group, 26 pre-surgical lateral cephalograms were also obtained. Inclusion criteria for the two groups were at least three of the following: (1) an ANB angle of 1 degree or less, (2) a Wits appraisal less than -4 mm, (3) an incisal overjet ≤ 0 mm, and (4) a Class III molar relationship. All lateral cephalograms were traced and digitised and a number of skeletal, dental and soft tissue variables were measured. The camouflage and surgical groups were also divided into premolar extraction and non-extraction subgroups to allow for a specific analysis of extraction effects.

Results: Before treatment, the surgical group demonstrated, on average, a more severe skeletal discrepancy and increased dental compensations, compared with the orthodontically camouflaged group. After treatment, the mean SNA angle was greater, the ANB angle was more positive, the Wits appraisal was closer to ideal and the lower incisors were less retroclined in the surgery group. There was a small mean reduction in horizontal chin projection in the surgery group compared with a small increase in the camouflage group. The mentolabial fold and the lower lip curve were deeper, on average, and the lips less retrusive after surgery. There was a mean increase in upper incisor proclination during treatment in both the surgical and camouflage groups with a greater increase in the camouflage group. There was a significant reduction in upper incisor proclination and a subsequent greater increase in the ANB angle associated with upper premolar extractions in the surgical group compared with the non-extraction group. Lower premolar extractions in the camouflage group resulted only in a deeper mentolabial fold compared with those treated without lower extractions.

Conclusions: Class III patients selected for surgical treatment are likely to have more severe pretreatment dental and skeletal discrepancies than those selected for camouflage treatment. Surgical treatment is associated with significant decompensation of the lower incisors but, ultimately, not the upper incisors. Class III patients treated with either camouflage or surgery treatment are likely to finish with slightly proclined upper incisors. Generally, surgical treatment results in greater skeletal change, involving normalisation of the skeletal base relationship, a reduction in chin prominence, fuller lips, and a more favourable lip and chin contour.

(Aust Orthod J 2015; 31: 138-148)

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Introduction

The aesthetic and functional goals of treatment for a skeletal Class III malocclusion can be achieved using one of four methods: (1) attempted modification of growth so that the jaw discrepancy is reduced or resolved, (2) tooth movements to compensate for the jaw discrepancy (orthodontic 'camouflage'), (3) a combination of the two, or (4) surgical movements to reposition the skeletal bases. Class III skeletal discrepancies have been reported to worsen in

adolescence,[1-3] an observation that may be related to larger increments and a longer duration of pubertal and post-pubertal mandibular growth in Class III subjects.[4-6] As a result, and having possibly outgrown earlier treatments, patients may often present for treatment in the latter stages of development with associated Class III characteristics such as reverse overjet and dental compensations, as well as the less typical anterior open bite or mandibular asymmetry. For patients in whom growth modification options are no longer a possibility, treatment must either involve orthodontic camouflage or a combined surgical-orthodontic approach.[7]

Successful camouflage treatment involves the incorporation of dentoalveolar compensations, which make the underlying skeletal problem less apparent, while allowing for an improvement in occlusion, function and aesthetics.[8-10] The main objectives of combined orthodontic and orthognathic surgery treatment are to correct the malocclusion, establish optimal function, and restore facial balance and harmony.[11,12] This often involves the correction of the main dental and skeletal variables to within a range of accepted cephalometric values.[12] A number of authors have attempted to provide specific cephalometric guidelines regarding the most appropriate treatment plan for any given patient.[8,13-16] While some treatment effects of orthodontic camouflage[17-20] and orthognathic surgery[12,21-23] have been documented in the literature, only rarely have these two methods been directly compared.[10,16]

Therefore, the present study was undertaken to evaluate differences in pre- and post-treatment characteristics of a group of Class III patients treated with either contemporary orthodontic camouflage or orthognathic surgery, and to compare the range of skeletal, dental and soft tissue changes that are likely to occur as a result of treatment, with a particular reference to the influence of premolar extractions on the resultant incisor positions and angulations.

Materials and methods

All records of Class III orthodontic camouflage and surgical-orthodontic patients were collected from one specialist practice. Ethics approval had been obtained from the Departmental Human Ethics Advisory Group of the University of Melbourne (DHEAG no: 1033996). Patients with cleft lip and/or palate, craniofacial syndromes or a mandibular anterior displacement were excluded, as well as any surgical patients who received a genioplasty as part of treatment. Patients who had not yet completed their adolescent growth spurt (as determined by cervical vertebral maturation status) were excluded. Inclusion criteria for the two groups were any three of the following: (1) an ANB angle less than 1 degree, (2) a Wits appraisal less than -4 mm, (3) an incisal overjet ≤ 0 mm, and (4) a Class III molar relationship.

Following the application of these criteria, 31 camouflage and 36 surgical patients were identified. High quality pretreatment (T1) and post-treatment (T3) lateral cephalograms, exhibiting good soft tissue definition with lips relaxed and teeth in occlusion, were available for all subjects. For the surgical group, 26 pre-surgical (T2) lateral cephalograms were also available. Patients were treated with or without extractions of premolar teeth and the specific extraction protocols are listed in Table I. Surgical patients were treated with either a maxillary advancement (N = 3), mandibular setback (N = 2) or both (N = 31). No patient received segmental maxillary surgery. While subjects were not selected based on the standard of the occlusal finish, all patients were treated with the aim of providing an ideal interdigitating occlusion as suggested by Roth[25] and Andrews.[26]

To obtain a more homogeneous sample, and therefore allow for direct comparison of the treatment outcomes of camouflage and surgical treatment in Class III patients with a similar degree of pretreatment skeletal discrepancy, patients from each group with an ANB angle between -1 and -5 degrees and a Wits appraisal between -6 and -13 mm were selected for further study. The patients in these relatively small 'borderline' camouflage (N = 10) and surgical (N = 10) groups were also treated with or without extractions.

Cephalometric analysis

All lateral cephalograms were hand traced by one investigator (K.G.) within a one-week period and then digitised and measured using Westcef

Table I. Extraction protocols for surgery and camouflage groups.

Extracted teeth	Surgery group (N = 36)	Camouflage group (N = 31)
None	22	13
Upper premolars	14	-
Lower premolars	-	18

cephalometric software (customised for the University of Melbourne by Mr Geoffrey West). The program automatically rotates the digitised points to create a Y-axis from the pterygomaxillary (PM) line through sphenoethmoidale,[27-32] in order to evaluate horizontal changes in cephalometric landmarks with reference to a relatively stable plane.[20,33-35] Superimposition on landmarks related to the cranial base[36] and the transfer of sphenoethmoidale (Se) and inferior pterygomaxillary points (Ptm) from the first to subsequent tracings were undertaken to ensure consistency of the PM line. To overcome difficulties in locating ANS, which is often recontoured during maxillary advancement procedures, the pretreatment maxillary tracing served as a template for post-treatment ANS identification. Each radiograph was traced and digitised randomly, without reference to its pair. A combination of skeletal and dental measurements from a number of conventional cephalometric analyses was used to assess the anteroposterior changes arising from treatment. Changes in lip morphology and chin position were assessed according to previously described methods (Figures 1 and 2).[30,37,38] A summary of the cephalometric measurements used in the present study is shown in Table II.

Statistical analysis

After digitisation, all measurements were imported into an Excel spreadsheet (Excel Office 2007; Microsoft Corp, WA, USA), where all linear cephalometric measurements were multiplied by 0.926 or 0.917, respectively, as necessary to correct for differences in magnification factors of 8% and 9%. The two major groups under study were also divided into premolar extraction and non-extraction subgroups to allow for specific analysis of extraction effects. The sample characteristics and treatment changes were then statistically analysed using a commercially-available statistical software package (PASW Statistics Version 18.0; SPSS Inc., IL, USA). Independent t-tests were used to test for differences between the camouflage and surgical groups, and between extraction and non-extraction subgroups, at the pretreatment, post-treatment and, where applicable, pre-surgical time points. Paired t-tests determined the statistical significance of the treatment changes occurring between time points for each main group and subgroup. Pearson's coefficients and associated levels of significance were calculated to determine the levels of correlation between the various pretreatment variables and changes observed with treatment.

Error measurement

In order to assess tracing and measurement error, radiographs of three camouflage and four surgical-orthodontic patients (10% of the sample) were randomly selected. The cephalograms were traced and measured twice, six weeks apart. At the 95% confidence level, the results of the paired t-test indicated that there were no significant differences between the first and second sets of measurements.
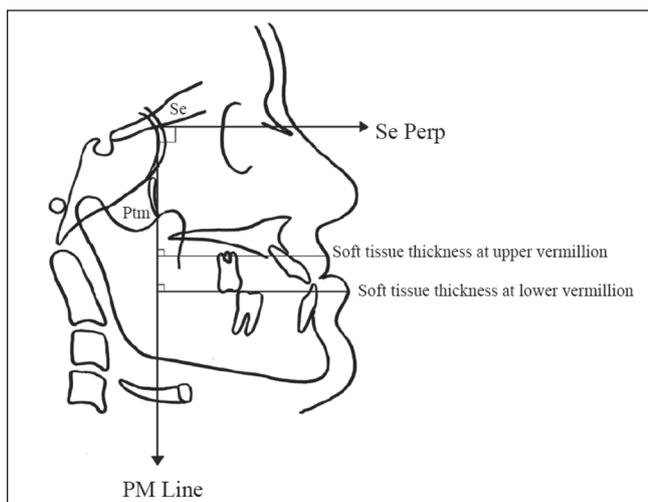

Figure 1. Pterygomaxillary line through points Se and Ptm, constructed horizontal line perpendicular to the PM line through Se; soft tissue thickness measurement of upper and lower lips.
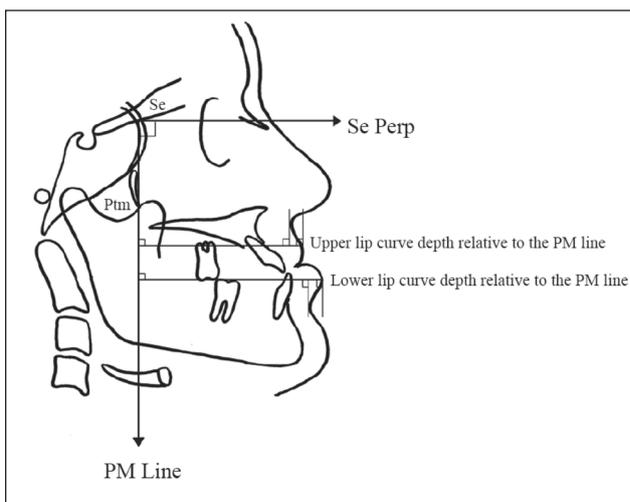

Figure 2. Measurement of upper and lower lip curve depths in relation to the PM line.

Table II. Definitions of lateral cephalometric measurements.

Cephalometric measurement	Definition
SNA (deg)	Angle: sella-nasion-point A
SNB (deg)	Angle: sella-nasion-Point B
ANB (deg)	Angle: point A-nasion-point B
WITS (mm)	Distance between projections from points A and B, drawn perpendicular to the FOP
Pog' to Pog (mm)	Distance between Pog' and Pog, drawn perpendicular to the PM line
OJ (mm)	Horizontal distance between the upper and lower incisor edges, parallel to the FOP
U1-Pal plane (deg)	Angle between the upper incisor and ANS-PNS
U1-SN (deg)	Angle between the upper incisor and S-N
U1-NA (mm)	Distance between the most anterior point on the upper incisor and N-A
L1-Md plane (deg)	Angle between the lower incisor and Go-Mn
L1 to NB (mm)	Distance between the most anterior point on the lower incisor and N-B
Interincisal angle (deg)	Posterior angle between the upper and lower incisor axes
Nasolabial angle (deg)	Angle between the most inferior point on tip of nose, subnasale and the upper vermillion border
Mentolabial angle (deg)	Angle between soft-tissue pogonion, soft tissue point B and the lower vermillion border
Upper lip to E plane (mm)	Distance between the most anterior point on the upper lip and the E plane
Lower lip to E plane (mm)	Distance between the most anterior point on the lower lip and the E plane
Upper lip thickness (mm)	Distance between the inner and outer aspects of the upper lip, perpendicular to the PM line
Lower lip thickness (mm)	Distance between the inner and outer aspects of the lower lip, perpendicular to the PM line
Upper lip depth (mm)	Difference in respective perpendicular distances of upper vermillion and soft-tissue point A to the PM line
Lower lip depth (mm)	Difference in respective perpendicular distances of lower vermillion and soft-tissue point B to the PM line

Results

There was considerable individual variation for all pre- and post-treatment measurements in both the surgical and camouflage treatment groups. This can be appreciated from the means and standard deviations presented in Tables III to VI.

Overall treatment effects for the total surgery and camouflage groups

Mean pre- and post-treatment cephalometric measurements for the total surgery and camouflage groups are presented in Table III. It is apparent that there were significant pretreatment differences in the average measurements for SNB, ANB, the Wits appraisal, incisal overjet, Pog' to Pog, U1 to NA and L1 to Md plane. The surgical group showed consistently greater deviation from accepted literature-based norms. Despite the fact that the lower incisors were

significantly more retroclined on average, the reverse overjet for the surgical group was only 2.5 mm more severe compared with the camouflage group. The nasolabial angle was also, on average, greater for the surgical group.

At the completion of active treatment in the surgery group, the mean SNA angle was greater, the ANB angle was more positive, the Wits appraisal was closer to ideal and the lower incisors were less retroclined and retropositioned in comparison with the camouflage group. The mentolabial fold and the lower lip curve were deeper and the lips less retrusive in relation to the E plane in the surgery group.

On average, there was a small treatment reduction in Pog' to Pog distance in the surgery group and a small increase seen in the camouflage group. However, there was wide individual variation. There was considerable mean reduction in the reverse overjet and an increase in lower incisal angulation in the surgery group. In

Table III. Cephalometric characteristics: surgery and camouflage groups.

Measure	Pretreatment (T1)				Post-treatment (T3)				Treatment change (T1–T3)			
	Surgery		Camouflage		Surgery		Camouflage		Surgery		Camouflage	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SNA	79.7	3.2	80.5	4.0	83.1**	3.5	80.5**	3.9	**3.4****	2.5	0.1**	1.2
SNB	83.5*	3.2	81.6*	4.1	81.6	3.2	81.4	4.1	**-1.9****	2.2	-0.2**	1.8
ANB	-3.8**	2.4	-1.2**	2.0	1.5**	2.4	-0.9**	2.2	**5.3****	2.7	0.3**	1.7
WITS	-11.5**	3.6	-7.2**	2.8	-4.0**	2.4	-6.0**	2.7	**7.4****	3.9	**1.1****	2.3
Pog' to Pog	61.6**	7.7	56.3**	6.3	60.1	8.8	57.7	6.0	**-1.5****	3.5	**1.5****	2.7
OJ	-2.7**	2.2	-0.2**	1.6	2.8	0.9	2.8	1.1	**5.4****	2.0	**2.9****	1.9
U1-Pal plane	117.9	7.2	116.1	7.5	121.8	8.1	121.2	7.2	**3.9**	7.3	**5.1**	7.5
U1-SN	109.0	8.0	107.2	6.7	111.1	7.7	112.8	7.6	**2.1***	5.7	**5.6***	7.5
U1-NA	6.9*	2.2	6.0*	1.5	6.3	2.2	6.9	1.8	**-0.6****	2.0	**0.9****	1.6
L1-Md Plane	79.8*	8.3	84.3*	6.8	87.4**	6.5	82.7**	5.7	**7.6***	7.4	**-1.6***	6.2
L1-NB	4.8	2.4	4.7	2.0	5.9**	1.4	3.8**	1.9	**1.1****	1.6	**-0.9****	1.7
Interincisal	135.0	12.2	133.3	9.2	124.2**	7.6	129.9*	9.2	**-10.9****	12.0	-3.5**	10.8
Nasolabial	104.0*	14.0	110.0*	9.6	108.7	13.4	108.7	9.1	**4.7****	9.3	-1.3**	8.0
Mentolabial	142.7	9.5	142.3	9.2	131.6*	7.5	137.1*	11.8	**-11.2***	8.9	**-5.2***	10.9
Upper lip-E plane	-6.6*	3.4	-5.0*	2.6	-3.4*	3.7	-5.3*	2.5	**3.3****	1.5	0.3**	1.6
Lower lip-E plane	-1.2	4.2	-1.3	3.1	-1.0	3.7	-2.4	2.7	**0.2***	1.5	**-1.2****	1.7
Upper lip thickness	15.6	3.0	14.2	3.6	14.5	3.5	15.4	2.6	-1.1**	2.7	1.3**	3.6
Lower lip thickness	12.8	1.9	12.5	2.9	13.2	2.8	13.8	1.9	0.4	2.8	**1.4**	2.7
Upper lip depth	5.6	2.6	5.2	3.1	6.4	3.6	5.0	1.8	0.7	2.6	0.2	3.1
Lower lip depth	3.9	2.0	4.4	1.9	5.7**	1.7	4.6**	1.6	**1.8****	1.3	0.2**	1.5

*Statistically significant difference between treatment methods, $p < 0.05$, ** $p < 0.01$
Bold values denote statistically significant difference between time points (T1–T3), $p < 0.05$

Table IV. Cephalometric hard-tissue changes with surgical treatment.

Measure	Pretreatment (T1)		Pre-surgical (T2)		Post-treatment (T3)		T1–T2		T2–T3		T1–T3	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SNA	80.1	2.8	80.3	3.1	83.6	3.2	0.2	1.4	3.3*	2.8	3.6*	2.6
SNB	83.7	3.0	83.9	3.0	81.7	2.6	0.2	1.5	-2.2*	1.9	-2.0*	2.4
ANB	-3.7	2.5	-3.5	2.1	1.9	2.1	0.1	1.2	5.5*	2.2	5.7*	2.5
WITS	-11.6	3.5	12.0	2.7	-4.1	2.3	-0.4	2.1	7.9*	3.0	7.5*	3.7
OJ	-2.9	1.7	-5.6	1.8	2.8	0.8	-2.7*	2.0	8.4*	2.1	5.7*	1.8
U1-Pal plane	118.6	7.3	118.0	7.3	122.0	7.8	-0.6	6.3	4.0*	6.0	3.4*	7.5
U1-NA	7.1	2.1	6.2	1.8	6.0	1.7	-0.8*	1.4	-0.2	1.5	-1.0*	2.0
L1-Md plane	80.0	8.1	86.7	7.3	86.6	7.0	6.7*	5.4	-0.1	3.9	6.6*	6.2
L1-NB	5.3	2.2	6.6	1.8	6.1	1.4	1.3*	1.5	-0.5*	0.7	0.9*	1.4
Interincisal	133.9	10.5	128.1	7.1	24.0	7.7	-5.8*	9.0	-4.1*	6.1	-9.9*	11.4

* Statistically significant difference between time points, $p < 0.05$

contrast, there were small reductions in reverse overjet and lower incisor angulation in the camouflage group. The mean measurements for the camouflage group still reflected considerable lower incisal compensation.

The mean pre- and post-treatment upper incisor positional measurements for the surgery and camouflage groups were similar. There was, however, a mean increase in upper incisor proclination during treatment in both groups with, on average, a greater increase in relation to SN in the camouflage group. There were also significantly greater changes in the nasolabial and mentolabial angles and in the relation of the upper lip to the E plane for the surgical group compared with the camouflage group.

The calculation of Pearson's coefficients highlighted a number of significant correlations amongst pre- and post-treatment measurements and changes with treatment. For the surgical group, the more severe the initial cephalometric measurement, the greater the change seen with treatment for the following: SNB ($r = 0.367$; $p < 0.05$), ANB ($r = 0.554$; $p < 0.01$), Wits appraisal ($r = 0.796$; $p < 0.01$), incisal overjet ($r = 0.909$; $p < 0.01$), upper incisal angulation ($r = 0.552$; $p < 0.01$) and lower incisal angulation ($r = 0.532$: $p < 0.01$).

For the camouflage group, strong positive correlations were found between pre- and post-treatment measurements for SNA ($r = 0.952$; $p < 0.01$), SNB ($r = 0.903$; $p < 0.01$), ANB ($r = 0.676$; $p < 0.01$) and the Wits appraisal ($r = 0.652$; $p < 0.01$), reinforcing the general observation that Class III camouflage treatment results in little change in the underlying jaw relationship. The camouflage group also revealed strong negative pre- and post-treatment correlations between upper incisor angulation and the nasolabial angle and the positions of the upper and lower lips in relation to the E plane. Those with more proclined upper incisors before treatment seemed to show smaller increases in upper incisor angulation with treatment ($r = -0.542$; $p < 0.01$).

Including immediate pre-surgical records

Mean pretreatment, pre-surgical and post-treatment hard tissue cephalometric measurements for the surgical group (N = 26) are presented in Table IV. It can be seen that there were significant mean changes in incisal overjet and the angulations of the upper and lower incisors during the pre-surgical period (T1 to T2). There were no obvious pre-surgical changes

in jaw relationship. As a result of surgery and final orthodontic detailing (T2 to T3), there were significant mean changes in the SNA, SNB and ANB angles, the Wits appraisal and upper incisal angulation. Average lower incisal changes were minimal from surgery through to the completion of active treatment. Combined orthodontic and orthognathic surgery treatment (T1 to T3) produced significant changes in all hard tissue study measurements.

Extraction effects

In the surgical group, the mean post-treatment ANB angulations were the only hard tissue measurements found to be significantly different in the non-extraction and upper premolar extraction groups. The mean post-treatment ANB for the extraction group was 3.7°, compared with 0.4° for the non-extraction group. For the upper extraction group, there was a significant mean reduction (1.9 mm) in the angulation of the upper incisors to NA, with no real change for the non-extraction group. On average, the maxillary extraction subjects were seen to have smaller pre- and post-treatment nasolabial angles, larger mentolabial angles and less retrusive upper and lower lips (Table V).

In the camouflage group, all mean pre- and post-treatment hard tissue measurements for the non-extraction and lower premolar extraction groups were found to be similar. The mean pre- and post-treatment values for the mentolabial angle were greater for the lower extraction group (Table V).

Borderline surgery and camouflage groups

Mean pre- and post-treatment cephalometric measurements for the borderline surgery and camouflage groups are presented in Table VI. It can be seen that there were no significant pretreatment differences in the means for any of the study measurements, except for the greater mean reverse overjet in the surgical group. With overall treatment, the mean changes in SNA, ANB, the Wits appraisal, incisal overjet and lower incisal angulation were greater in the borderline surgical group than in the borderline camouflage group. All of these measurements moved closer to traditionally-accepted cephalometric norms than in the camouflage group. It is notable, however, that the mean post-treatment ANB angle and the Wits appraisal for this surgery group still reflected a mild Class III relationship. On average, the lower lip was

Table V. Cephalometric soft tissue characteristics of extraction and non-extraction subgroups.

| | Pretreatment (T1) | | | | Post-treatment (T3) | | | |
| | Extraction | | Non-extraction | | Extraction | | Non-extraction | |
Surgery	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Nasolabial	96.4*	10.6	108.3*	13.0	102.6*	13.9	112.2*	12.1
Mentolabial	147.1*	9.6	140.2*	8.6	135.4*	5.2	129.4*	7.9
Upper lip-E plane	-4.0*	3.0	-8.1*	2.6	-0.5*	2.3	-5.0*	3.3
Lower lip-E plane	1.8*	3.0	-2.9*	4.0	1.7*	2.4	-2.5*	3.5
Upper lip depth	7.0*	2.8	4.8*	2.2	8.5*	4.2	5.1*	2.7
Lower lip depth	4.5	1.4	3.6	2.2	6.5*	1.1	5.3*	1.9
	Extraction		Non-extraction		Extraction		Non-extraction	
Camouflage	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Nasolabial	108.0	7.7	112.9	11.5	108.6	9.7	108.9	8.7
Mentolabial	145.6*	7.9	137.6*	9.1	140.8*	7.7	132.0*	14.6
Upper lip-E plane	-3.9*	2.6	-6.5*	1.8	-4.7	2.6	-6.2	2.3
Lower lip-E plane	-0.1*	3.2	-2.9*	2.0	-1.5*	2.5	-3.7*	2.5
Upper lip depth	6.1	3.7	4.1	1.5	5.3	1.9	4.7	1.7
Lower lip depth	4.7	2.0	3.8	1.6	4.6	1.7	4.5	1.5

Extraction indicates treatment involved upper premolar extractions for the surgery group, and lower premolar extractions for the camouflage group.
Non-extraction indicates treatment that did not involve premolar extractions, but may have included third molar extractions.
*Statistically significant difference between extraction and non-extraction groups for each treatment method, $p < 0.05$

less retrusive in relation to the E plane after treatment in the surgical group and the lower lip curve was deeper.

Discussion

To reduce the possibility of selection bias in this retrospective study, strict exclusion and inclusion criteria were determined prior to sample collection, and all subjects who fulfilled these criteria were studied. As all had been treated by a single practitioner, variables such as clinician expertise, appliance type and treatment mechanics were able to be controlled.

Camouflage treatment

Previous cephalometric studies of Class III patients treated with orthodontic camouflage have consistently demonstrated additional increases in upper dental compensations, regardless of the severity of the pretreatment malocclusion.[10,16-19] Of these studies, only Rabie et al. showed little change in upper incisor angulation with treatment. This is not surprising given that 12 of the 13 patients in their camouflage sample received both upper and lower arch extractions.[16] In the present study, additional upper dental compensations did occur, as shown by mean 5.1° and 5.6° increases in upper incisor angulation to the palatal plane and SN line, respectively. This is consistent with previous reports of increased upper proclination of between 4.9° and 5.9°.[10,18,19]

A number of authors have also documented lower incisor retroclination of between 3.5° and 7.1°.[10,16,18,19] However, in the current sample, the lower incisors experienced only a minimal amount of retraction (mean = 0.9 mm) while maintaining essentially the same angulation. This is despite the fact that lower arch extractions had been performed in 60% of these subjects. Differences in treatment methods including selection of bracket prescription, the use of Class III elastics and the chosen mechanics for space closure may explain the inconsistency between these findings and those in previous reports. It may also have been that the clinician was more prepared to consider surgery as a routine option rather than to be used as a last resort after all compensating treatment had been attempted.

The results of the present study are consistent with previous findings in that the SNA, SNB and

Table VI. Mean pre- and post-treatment cephalometric measurements for borderline surgery and camouflage groups.

Surgery	Pretreatment (T1)				Post-treatment (T3)				Treatment change (T1–T3)			
	Surgery		Camouflage		Surgery		Camouflage		Surgery		Camouflage	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SNA	81.5	3.3	79.3	3.9	84.1*	2.8	79.9*	3.9	**2.6***	2.5	0.6*	1.5
SNB	84.4	3.0	82.3	3.9	82.7	2.9	82.1	4.3	**-1.7**	2.0	-0.2	1.7
ANB	-3.0	1.1	-3.0	1.0	1.3**	1.8	-2.2**	1.8	**4.3*** *	2.0	0.8**	2.0
WITS	-9.4	2.1	-9.9	1.8	-4.2*	2.9	-7.8*	2.8	**5.2*** *	2.5	**2.1*** *	2.2
Pog' to Pog	57.6	3.9	57.7	4.6	56.0	4.5	60.2	5.0	-1.6**	3.1	**2.4*** *	2.6
OJ	-2.3*	0.9	-0.6*	1.7	2.9	0.9	2.5	1.1	**5.2*** *	1.3	**3.1*** *	1.1
U1-Pal plane	117.5	3.9	118.6	8.6	126.2	6.8	121.1	7.8	**8.7**	7.2	2.5	5.8
U1-SN	110.7	6.0	108.9	7.0	114.6	5.7	113.3	6.5	3.9	6.4	4.3	6.9
U1-NA	6.9	1.8	6.6	1.5	6.7	2.0	7.4	1.2	-0.2	2.0	0.8	1.2
L1-Md Plane	83.6	5.8	83.3	4.0	90.2**	3.3	81.6**	6.3	**6.6*** *	5.6	-1.7**	5.0
L1-NB	5.4	1.7	4.1	1.6	5.9**	1.2	2.9**	1.8	0.5*	1.2	-1.2*	1.7
Interincisal	132.8	9.0	134.1	7.1	119.2**	4.9	133.6**	10.9	**-13.6*** *	11.3	-0.6**	6.5
Nasolabial	107.2	11.3	109.1	10.0	109.5	10.9	106.8	10.3	2.3	6.7	-2.4	9.6
Mentolabial	140.1	8.9	138.3	6.7	131.3	9.6	135.3	9.5	**-8.8**	6.5	-3.1	10.8
Upper lip-E plane	-5.3	3.1	-5.1	3.3	-2.0*	3.0	-5.4*	3.0	**3.3*** *	1.1	-0.3**	1.6
Lower lip-E plane	0.5	2.8	-0.5	2.4	0.2*	2.2	-2.6*	2.1	-0.2**	1.0	**-2.1*** *	1.4
Upper lip thickness	13.9	2.9	14.7	2.6	12.8	4.9	15.7	2.3	1.1	3.6	1.0	2.1
Lower lip thickness	12.7	1.2	13.4	1.7	12.3	4.6	14.3	1.7	-0.4	4.6	**0.9**	0.8
Upper lip depth	5.6	2.6	5.4	2.1	6.2	2.8	5.8	1.9	0.5	1.3	0.3	1.6
Lower lip depth	5.2	1.3	4.3	1.0	6.3**	1.1	3.9**	1.1	**1.2*** *	1.0	-0.4**	1.1

* Statistically significant difference between treatment methods, $p < 0.05$, ** $p < 0.01$
Bold values denote statistically significant difference between time points (T1–T3), $p < 0.05$

ANB angles are unlikely to significantly improve following camouflage treatment,[10,16,39] with only Lin and Gu reporting a statistically significant 2° mean improvement in the ANB angle, mostly as a result of the anterior movement of point A.[18] Their camouflage sample was, however, considerably more Class III, dentally and skeletally, before treatment commenced compared with the current or previous studies.

The lower lips of Class III camouflage patients are typically observed to become more retrusive following retraction of the lower incisors,[16,18,39] and the upper lips often,[18,39] but not always,[16] follow the forward movement of the upper incisors. In the present study, camouflage treatment resulted in little change to the upper lip, while a small but statistically significant retraction of the lower lip was observed. In addition, a 5.2° decrease in the average mentolabial angle indicated a mild improvement in the lower lip profile with treatment. Unfortunately, the literature provides no basis for comparison of this measurement. Only a limited number of previous Class III camouflage studies have incorporated soft tissue analyses, and, unfortunately, there are significant differences related to inclusion criteria, sample homogeneity, subject ethnicity, the prescription of extractions, and the chosen treatment mechanics.[16,18,20,39] Despite these problems, a common observation is that some facial improvement can be achieved with camouflage treatment, although the capacity for change is usually limited. Most Class III characteristics are usually still present at the completion of active camouflage treatment.[10,16-18]

Surgical treatment

Decompensation of the lower incisors with combined surgical and orthodontic Class III treatment has been reported to occur with variable success.[10,12,16,21,23,40] Some investigators have observed that lower incisors

remain retroclined at the end of treatment,[12,40] others have reported successful pre-surgical decompensation, followed by 'round-tripping' back to the original compensated positions.[10,23] In addition, others have shown that lower incisor pre-surgical decompensation can be maintained until the completion of appliance treatment, which is consistent with the current findings.[16,21] The results of the present study suggest that more severely retroclined lower incisors experience a greater magnitude of decompensation during treatment. This is not surprising and differences in pretreatment severity of the malocclusion may therefore partly explain the variability of the previously reported findings. In addition, Johnston et al. found that incomplete decompensation of the mandibular incisors was four times more likely to be seen when lower arch extractions had been performed.[12] It is therefore likely that the significant decompensation seen in the current sample, though not strictly reaching cephalometric norms, was relatively successful because no patient received lower arch extractions as part of their surgical-orthodontic treatment. Previous camouflage studies have not included lower arch premolar extractions as a study variable.[16,21,23,40] While lower incisor decompensation was successful over the treatment period for this surgical group, without the availability of long-term follow-up records, it is unclear whether the incisor positions will be maintained in the long term.

Capelozza et al. suggested that orthodontists are strongly motivated to remove compensations in the lower arch, because of the visible presence of crowding which can generally be resolved by improving the lower incisor angulation.[23] In contrast, there appears to be bias against upper extractions in the comprehensive treatment of Class III surgical cases,[23,40] with reported upper extraction rates as low as 27%.[12] Some Class III patients may require palatal expansion for transverse correction and perhaps the minor space gained from this procedure and the subsequent resolution of crowding might have suggested to clinicians that extractions were not necessary. Perhaps treatment may also have been viewed as simpler and more efficient without premolar extractions. Finally, it is possible that upper extractions might have been avoided in the belief that the limiting of upper incisor retraction would increase the stability of the final result by reducing the necessary amount of surgical movement. Extractions may have even been avoided to spare the patient from a two-jaw procedure, by limiting the

surgery to a mandibular setback. Unfortunately, these misconceptions may still exist, despite the observation that dental, skeletal and soft-tissue measurements, in adequately decompensated Class III patients,[23] especially when upper premolars have been extracted,[12] are less likely to deviate from accepted anteroposterior norms at the end of active treatment.

A number of previous investigators have confirmed that the upper incisors often still remain proclined, after the pre-surgical phase and at the completion of active treatment.[10,12,21,23,40] However, only one study[12] specifically included upper extractions as a treatment variable, and, even then, the sample was not divided on the basis of this variable, nor were any cephalometric data offered to specifically highlight the effects of extraction on incisor position or angulation. In the present study, surgical subjects treated with upper extractions (approximately 40%) experienced greater surgical movements. Both extraction and non-extraction treatments, however, still resulted in successful normalisation of the anteroposterior skeletal bases, at least as determined by the ANB angle. While more upper incisor retraction was generally seen after upper extractions, there was no statistically significant difference in upper incisor angulation between the extraction and non-extraction subgroups before, during or after treatment. In both groups, the upper incisors remained significantly proclined (mean angulation to the palatal plane, 122º) at the end of active treatment. It appears that, during the post-surgical detailing phase, there is a tendency for the return of upper incisor compensations as the bones, muscles and teeth settle into their new positions. Future research that considers the severity of pretreatment crowding and the use of maxillary expansion devices might help to determine when, if ever, upper incisor decompensation to cephalometric norms is actually achieved, and how this might impact on the quality of the overall result. In addition, it should be remembered that decisions regarding the desired amount of decompensation, and hence the potential amount of surgical movement, should be made with full clinical consideration of the profile changes likely to accompany such treatment.[41,42] It has been proposed that complete decompensation in the sagittal plane to 'normal' or ideal cephalometric values may necessitate excessive correction of one or both jaws in some cases, and actually lead to poorer aesthetic results.[23]

Borderline cases

Only two previous studies have involved the direct comparison of pre- and post-treatment morphological characteristics and treatment changes in similar skeletal Class III patients, treated with either camouflage or surgery.[10,16] As discovered by Troy et al., a major difficulty encountered when attempting to compare such groups is gathering a homogeneous sample.[10] The influence of pretreatment morphological differences must be kept in mind whenever treatment outcomes are to be compared retrospectively.[43] In the present study, statistical analysis of borderline camouflage and surgery subjects was undertaken in an attempt to circumvent this problem. Despite the fact that the borderline samples were quite small, valuable observations were still able to be made. Although the two borderline groups revealed no significant differences related to pretreatment anteroposterior severity, the borderline surgery group displayed a greater reverse overjet (mean, -2.3 mm) than the camouflage group (mean, -0.6 mm). This suggests that the appearance of a reverse overjet may be an influential factor in the camouflage/surgery treatment planning decision, even when other skeletal, dental and soft tissue factors are found to be comparable. Clinicians should expect that both treatment methods are likely to result in further proclination of the upper incisors, although improvements in lower incisor angulation should only be expected in surgical cases. A significant improvement in the soft tissue profile of the lower face is also likely to be observed in surgical patients, regardless of whether a genioplasty has been performed as part of surgical treatment.

In general, clinicians make treatment decisions based on their detailed assessment of individual dental, skeletal and soft tissue characteristics. Any proposed compensatory tooth movements will be limited by the morphology of the surrounding skeletal structures, especially the lingual cortex of the mandibular symphysis. The results of the present study highlight that, while considerable upper and/or lower incisal compensation may often be part of Class III camouflage treatment, the possibility of completing treatment in many cases with incisal positions and angulations close to the normal range should also be noted.

Conclusions

While accepting individual variation and the limitations of any cephalometric study, the following clinical conclusions may be drawn:

1. Class III patients selected for camouflage treatment are likely to have less severe pretreatment dental and skeletal discrepancies than patients selected for surgical treatment.

2. Generally, Class III surgical treatment is likely to result in greater skeletal changes, including normalisation of the skeletal bases and a small reduction in chin prominence. It is unlikely that there will be any clinically significant alteration to the underlying Class III skeletal pattern in patients treated with orthodontic camouflage.

3. Class III surgical treatment is likely to be associated with significant decompensation of the lower incisors, but not the upper incisors, which seem to procline further, whether upper premolars have been extracted or not, and finish at similar angulations to those in camouflage patients.

4. Class III camouflage treatment is not necessarily associated with retroclination of the lower incisors. However, treatment may result in minimal retraction of these teeth and the lower lip, and involve some deepening of the mentolabial fold, with or without lower premolar extractions.

5. While there may be a general improvement in soft tissue lip positions and contours with either treatment method, there is likely to be a wide range of individual variation. Generally, Class III surgical patients are likely to finish treatment with fuller lips and a more favourable lower lip and chin contour than camouflage patients.

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