Retreatment of Skeletal Class III Malocclusion: Insignia[™] CAD-CAM Custom Appliance for Orthodontics and Orthognathic Surgery

Abstract

History: Despite orthodontic treatment at age 12yr, a 17yr female presented with a severe skeletal Class III malocclusion.

Etiology: Inadequate dental loading contributed to constricted arches, and airway insufficiency resulted in low tongue posture with mandibular protrusion.

Diagnosis: In centric occlusion (Co), the facial profile was concave (-12°), lips were retrusive to the E-line (-9mm/-3mm), and occlusal relationships were bilateral Class III with anterior and posterior crossbite. Skeletally, the maxilla was retrusive (SNA 78°), mandible was protrusive (SNB 86°), and the lower midline was deviated 4mm to the left. Crowding was severe in both arches (-13mm/-22mm), resulting in block-out of upper canines (U3s) and lower second premolars (L5s). The ABO Discrepancy index (DI) was 49.

Treatment: A custom, stainless steel fixed appliance (InsigniaTM System, Ormco, Brea, CA) was constructed to achieve ideal alignment with full-sized rectangular archwires. Digital set-up via computer-assisted design (CAD) specified custom brackets, produced with computer-assisted manufacturing (CAM). Treatment sequence was: 1) extraction of U4s and L5s, 2) progressive straight-wire alignment, 3) space closure, 4) two-jaw orthognathic surgery, 5) reduction genioplasty, and 6) finishing.

Outcomes: Seventeen months of treatment resulted in an excellent ABO Cast-Radiograph Evaluation (CRE) score of 17 with near ideal dental esthetics (Pink & White Score 1).

Conclusions: Surgical correction of severe skeletal Class III malocclusion was very efficient because precise presurgical alignment facilitated surgical correction of the intermaxillary skeletal discrepancy. (J Digital Orthod 2020;57:28-45)

Key words:

InsigniaTM system, passive self-ligating bracket, archwire sequence, custom bracket, high Le Fort I osteotomy, oblique ramus osteotomy, genioplasty

Introduction

Skeletal Class III malocclusion is a prognathic facial aberration in the sagittal plane that may involve maxillary retrusion, mandibular protrusion and/or abnormal facial height.¹ In addition, deviation of the maxilla and/ or mandible in the frontal plane is common.² The typical facial morphology for Asians with a severe skeletal Class III malocclusion is midface deficiency, mandibular prognathism and a prominent chin (*Fig. 1*).^{1,2} Particularly when associated with midline deviation, midface deficiency may require both orthodontics and orthognathic surgery. The InsigniaTM system (*Ormco, Brea, CA*) produces a custom stainless steel (SS) fixed appliance that achieves precision alignment of each arch to facilitate optimal intermaxillary occlusion during



Dr. Hsin-Yin Yeh, Editor, Journal of Digital Orthodontics (Upper left)

Dr. Edward Chen, Attending Physician, Department of Oral and Maxillofacial Surgery Wan-Fang Hospital, Taipei Medical University (Upper center)

Dr. Kuan-Chou Lin, Department Chief, Department of Oral and Maxillofacial Surgery Wan-Fang Hospital, Taipei Medical University (Upper right)

> Dr. Chris H. Chang, President, Beethoven Orthodontic Center Publisher, Journal of Digital Orthodontics (Lower left)

Dr. W. Eugene Roberts, Editor-in-chief, Journal of Digital Orthodontics (Lower right)

and following orthognathic surgery.³ Dental nomenclature for this report is a modified Palmer notation.²⁻⁴ The four quadrants are upper right (*UR*), upper left (*UL*), lower left (*LL*), and lower right (*LR*). Permanent teeth are numbered 1-8 from the midline.



Fig. 1: Pre-treatment facial and intraoral photographs

Diagnosis, History and Etiology

A 17-year-old female was concerned about her dentofacial esthetics: profile, smile and prognathic chin (Figs. 1-4). Orthodontic treatment had been rendered at age 12 yr, and the alignment of the maxillary incisors was maintained with a fixed lingual retainer. Medical history was noncontributory. Etiology was deemed an abnormal adolescent growth pattern due to inadequate posterior occlusal loading and airway insufficiency that resulted in low tongue posture and mandibular protrusion.² Rather than being classified as a "relapse," the present malocclusion reflects a continuing manifestation of abnormal development that continued into adolescence. Facial evaluation revealed a severely concave profile (-13°) with a retrusive upper lip. Despite deficiency in maxillary height, lower facial height was excessive (59%) consistent with excessive growth of the mandible. In the frontal view, the face was asymmetric and the chin was deviated to the left ~5mm (Fig. 2). Intraoral examination revealed bilateral Class III buccal segments in centric occlusion (Co) (Fig. 3). Anterior crossbite (-3mm) extended into the maxillary first premolar (U4) area (Fig. 3). The lower midline was shifted 4mm to the left relative to the upper midline (Fig. 4). Both arches were severely crowded (-13mm/-22mm), resulting in block-out of maxillary canines (U3s) to the labial, and mandibular second premolars (L5s) to the lingual.

Panoramic radiography (*Fig. 5*) revealed three unerupted third molars (*UR8, UL8, and LR8*). The mandibular condyles were relatively symmetric (*Fig.*



Fig. 2:

Blue lines mark the midlines at initial occlusal contact for the maxilla, mandible and chin. Note the unattractive smile is associated with a progressive 3-5mm deviation to the left of the lower arch.



Fig. 3: Pre-treatment dental models (casts)







Fig. 5:

Pre-treatment panoramic radiograph shows the fixed retainer for the previous maxillary.



Fig. 6:

Pre-treatment TMJ transcranial radiographs show the right (R) and left (L) sides in the rest and open positions. The mandibular condyles are outlined in red.



Fig. 7: Pre-treatment lateral cephalometric radiograph in Co

6), consistent with a lack of signs and symptoms of temporomandibular joint dysfunction (*TMD*). Pretreatment cephalometric analysis (*Fig. 7, Table 1*) documented a skeletal Class III relationship (*ANB* -8°) due to both a retrusive maxilla (*SNA 78*°) and a prognathic mandible (*SNB 86*°). Upper incisors were labially inclined and protruded (*U1 to SN 110°; U1 to NA 8mm*). Lower incisors were tipped posteriorly and retruded (*L1 to MP 68°; L1 to NB 1mm*). The severe skeletal malocclusion had an ABO Discrepancy Index (*DI*) of 49 (*Worksheet 1*).

CEPHALOMETRIC SUMMARY					
SKELETAL ANALYSIS	5				
	PRE- Tx	PRE- Sur	POST- Tx	DIFF.	
SNA° (82°)	78°	78°	78°	0°	
SNB° (80°)	86°	86°	81°	5°	
ANB° (2°)	-8°	-8°	-3°	5°	
SN-MP° (32°)	35°	35°	37°	2°	
FMA° (25°)	28°	28°	30°	2°	
DENTAL ANALYSIS					
U1 To NA mm (4 mm)	8 mm	8 mm	10 mm	2 mm	
U1 To SN° (104°)	108°	11°	11°	3°	
L1 To NB mm (4 mm)	1 mm	4 mm	4 mm	3 mm	
L1 To MP° (90°)	68°	85°	95°	17°	
FACIAL ANALYSIS					
E-LINE UL (-1 mm)	-9 mm	-8 mm	-3 mm	6 mm	
E-LINE LL (0 mm)	-3 mm	0 mm	-2 mm	1 mm	
%FH: Na-ANS-Gn (53%)	59%	58%	58%	1%	
Convexity: G-Sn-Pg' (13°)	-12°	-15°	-2°	10°	

Table 1: Cephalometric summary



Fig. 8:

Digital alignment of each arch was coordinated for optimal intermaxillary digitation.



Fig. 9:

Simulation of the final alignment in intermaxillary occlusion is an ideal Class I relationship. See text for details.

Treatment Planning

Treatment objectives were: (1) increase facial convexity via upper lip protrusion, lower lip retraction, and posterior movement of the chin; (2) resolve crowding in both arches with premolar extraction; (3) correct anterior and posterior crossbites; (4) establish ideal overjet and overbite; and (5) achieve Class I molar and canine relationships bilaterally.

Skeletal Class III malocclusion in non-growing patients can be orthodontically masked with dentoalveolar camouflage or skeletally corrected with dentofacial alignment and orthognathic surgery. Instead of premolar extractions, mandibular arch crowding and anterior crossbite can be corrected by retracting the lower arch with mandibular buccal shelf bone screws,² but that approach would not correct the concave facial profile. After a thorough discussion of treatment options, the patient selected the following treatment plan: (1) extract U4s and L5s; (2) install a custom SS fixed appliance (*Insignia*TM); (3) align both arches; (4) close space; (5) correct the intermaxillary discrepancy with orthognathic surgery; (6) decrease chin height with reduction genioplasty; and (7) finish.

Progress

Two months following the extractions, an intraoral scan was performed to construct the digital appliance. After the U3s erupted into the extraction sites, the entire dentition was bonded with a 0.022-



Fig. 10:

A progressive series of maxillary occlusal photographs show alignment progress in months (M) from the start (0M) until one month before the end of treatment (16M). The archwires are specified for each interval. See text for details.



Fig. 11:

A corresponding series of mandibular occlusal photographs show alignment progress at sixteen months of active treatment. See text for details.



Fig. 12: Pre-surgical alignment is shown after ten months of active treatment.



Fig. 13: Pre-surgery panoramic radiograph

in slot, passive self-ligating appliance. All archwires, auxiliaries and elastics were supplied by the same manufacturer (*Ormco Corporation, Brea CA*). To disarticulate the arches during initial alignment, posterior bite turbos were constructed on the occlusal surfaces of the L7s with Fuji II® Type II glass lonomer cement (*GC America, Alsip IL*). Treatment progress and sequencing details are shown in Figs. 10-16 and Table 2. After 17 months of active treatment, all fixed appliances were removed, and

lingual fixed retainers were constructed on maxillary incisors and from canine to canine in the lower arch.

Results

The patient was satisfied with the harmonious facial profile and optimal lip protrusion (*Fig. 17*). Class I buccal relationships and a near ideal functional occlusion were achieved (*Figs. 18 and 19*). The panoramic radiograph documented adequate root parallelism (*Fig. 20*). TMJ imaging was within normal limits (*Fig. 21*). Slight to moderate apical root resorption was noted on maxillary incisors both before (*Fig. 6*) and after treatment (*Fig. 20*). Thus, loss of root structure was associated with the initial treatment at age 12yr, but there was no appreciable exacerbation during retreatment at age 17yr.



Fig. 14: Pre-surgery lateral cephalometric radiograph



Fig. 15:

A progressive series of right buccal photographs reveal alignment from the start (0M) to the end (17M) of treatment. See text for details.

Appointment	Archwire	Notes
1 (0 month)	U/L: 0.014-in Damon CuNiTi	Disarticulation with posterior bite-turbos constructed with Fuji II Type II Glass lonomer cement (GC America, Alsip IL) on the occlusal surfaces of the L7s.
2 (2 months)	U/L: 0.018-in Damon CuNiTi	
3 (4 months)	U/L: 0.014x0.025-in Insignia CuNiTi	
4 (6 months)	U/L: 0.019x0.025-in Insignia CuNiTi	
5 (8 months)	U/L: 0.021x0.025-in Insignia CuNiTi	Pre-surgery records were taken.
6 (10 months)	U: 0.019x0.025-in Insignia SS L: 0.021x0.025-in Insignia CuNiTi	Pre-surgery records were taken: intra- and extra-oral photos, ceph, panoramic x-ray, and impression (Figs. 12-14). Drop-in hooks were placed in each bracket.
Surgery (11 months)	U: 0.019x0.025-in Insignia SS L: 0.021x0.025-in Insignia CuNiTi	 Bimaxillary surgery (Fig. 16): 1. High Le Fort I osteotomy to advance the maxilla 3mm. 2. Bilateral oblique ramus osteotomy for mandible setback. 3. Genioplasty: reduce the chin 5mm in height.
7 (12 months)	U: 0.019x0.025-in Insignia SS L: 0.021x0.025-in Insignia CuNiTi	Post-surgery records were taken: Extra-oral photos, ceph, and panoramic x-ray.
8 (13 months)	U/L: 0.014x0.025-in Insignia CuNiTi	Rebonded the U2s and UR7
9 (14 months)	U/L: 0.021x0.025-in Insignia CuNiTi	3D alignment
10 (16 months)	U/L: 0.016 SS	Finishing bends and up & down elastics
11 (17 months)		Debonding

Table 2: Treatment sequence.



Fig. 16:

Post-operative cephalometric radiograph shows the facial profile following genioplasty and surgical repositioning of the jaws.

Cephalometric superimposition before treatment compared to that immediately before orthographic surgery (*Fig. 22*) showed both arches were aligned over the apical base of bone. The lower incisor and lip were ~4mm more protrusive. Cephalometric superimposition after surgical treatment (*Fig. 23*) documented: 1) maxilla was moved anteriorly and superiorly; 2) mandible was moved posteriorly; and 3) symphyseal height was decreased. The concave facial profile was corrected to a slightly convex (-2°) relationship consistent with less chin prominence (*Table 1*). The ABO Cast-Radiograph Evaluation (*CRE*) score was 17 points (*Worksheet 2*). Residual CRE discrepancies were primarily individual tooth alignment and occlusal contacts. The Pink and White dental esthetic score was a near ideal 1 point (*Worksheet 3*). The patient was well satisfied with the esthetic and functional correction of her severe malocclusion (*Fig. 17*).

Discussion

Insignia[™] is a CAD/CAM process for producing a custom SS fixed appliance system. A virtual set-up of the final occlusion specifies the manufacture a fixed

appliance to achieve ideal final alignment at the end of treatment with the final (*full-sized*) archwires.²⁻⁹ Torque compensations are applied to resist applied mechanics to align the arches.³⁻⁵ Precise presurgical alignment of coordinated arches is particularly advantageous for orthognathic surgery because the coordinated arches are surgically positioned in an ideal intermaxillary occlusion. The surgeon is guided by the final occlusion rather than an interocclusal orthotic. Furthermore, minimal if any detailing is required to achieve the fine outcome.



Fig. 17:

Post-treatment facial and intraoral photographs document the final alignment with fixed retention bonded on the maxillary incisors and from cuspid to cuspid in the lower arch.



Fig. 18: Post-treatment dental model (casts)



Fig. 19: Post-treatment cephalometric radiograph

Digital set-up of an ideal 3D alignment for each arch was based on leveling and aligning the dentition over supporting bone. Torque compensations were necessary to compensate for unusual dental anatomy and/or planned alignment mechanics. The final set-up was finished and detailed as a digital simulation of the post-surgical result. Clinician approval of the InsigniaTM set-up was based on an optimal intermaxillary occlusion.³⁻⁵ Presurgical orthodontic treatment followed the steps specified by InsigniaTM to achieve an ideal alignment of each arch over the apical base of bone (*Figs. 10 and 11, Table 2*).



Fig. 22: Superimposed cephalometric tracings before treatment (black) and prior orthographic surgery (blue). See text for details.

Surgical treatment of midface deficiency may require malar process augmentation via advancement of the maxilla with conventional Le Fort I, high Le Fort I, Le Fort II, or Le Fort III osteotomy (Fig. 24).⁷⁻¹⁰ The surgical procedure depends on the diagnosed anomaly and the desired outcome. Patients with a midface deficiency and flat malar eminences tend to have a gaunt appearance consistent with advanced age and sad (*depressed*) emotions.¹¹ Conventional Le Fort I osteotomy changes the soft tissue labial to the maxilla but does not correct midface hypoplasia. High Le Fort I osteotomy improves zygomatic prominence and soft tissue changes in the rectangular areas between the infraorbital foramen and the upper lip. This technique advances the infraorbital area and maxilla in an anterior direction (Fig. 24).^{12,13} For the present patient, the high LeFort I was indicated to correct severe midface



Fig. 20: Post-treatment panoramic radiograph



Fig. 21:

Post-treatment TMJ transcranial radiographs show the right (R) and left (L) sides in the rest and open positions. The contours and articular relationships are comparable to the start of treatment (Fig. 6).



Fig. 23:

Superimposed cephalometric tracings show dentofacial changes resulting from 17 months of active treatment (red) compared to the pretreatment position (black). See text for details.



Fig. 24:

Left: Le Fort I osteotomy (blue dotted line) is compared to a high Le Fort I osteotomy (pink dotted line). The osteotomy for a reduction genioplasty procedure is shown with a red line.

Right: Post-operative 3D (CBCT) radiograph shows the frontal view following high Le Fort I and genioplasty osteotomies.

retrusion. As defined in previous reports,¹²⁻¹⁴ the surgical correction of the present patient produced enhanced zygomatic prominence bilaterally to improve midface esthetics (*Fig.* 25).

Intraoral vertical ramus osteotomy (*IVRO*) is widely used to correct mandibular prognathism. The advantages of IVRO include a less complex surgical procedure and lower incidence of inferior alveolar nerve injury. However, IVRO has some disadvantages compared with sagittal split ramus osteotomy (*SSRO*). Condylar displacement and bony interference can be a major IVRO complication.¹⁵⁻¹⁹ Kawase-Koga et al.¹⁹ reported that an oblique osteotomy from the mandibular notch to mandibular angle avoids condylar displacement complications with IVRO. For the present patient, condylar position was monitored with manual manipulation of the mandible during surgery as well as with TMJ imaging (*Figs. 6 and 21*). No complications were noted or reported.

Orthognathic surgical procedures are facilitated by ideal presurgical alignment of the arches over the apical base of bone. Optimal occlusion is achieved when the arches are surgically positioned in the prescribed intermaxillary position. It is not necessary to use a plastic orthotic to surgically position the jaws. Direct visualization of the final result guides the surgeon in refining the osteotomy and fixation procedures. Furthermore, little if any detailing is needed postoperatively. A CAD-CAM arch alignment appliance is a cost effective approach for facilitating the surgical-orthodontic correction of a severe skeletal malocclusion.



Fig. 25:

Pre-treatment (left) and post-treatment (right) oblique facial photos reveal the improved facial esthetics following repositioning of the jaws and augmentation of the zygomatic prominences bilaterally.

Conclusions

- 1. Incisal torque compensations prevent third order alignment problems during presurgical alignment.
- Digital set-up of the desired final alignment is advantageous for orthognathic surgery cases because intermaxillary occlusion guides the optimal repositioning of the arches.
- 3. High Le Fort I osteotomy improves zygomatic prominence for patients with anteroposterior deficiency in the infraorbital and maxillary area.
- 4. Precise presurgical alignment facilitates both the surgical procedure(s) and postoperative finishing.

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Discrepancy Index Worksheet

49

8

TOTAL D.I. SCORE



0 mm. (edge-to-edge)	=	
1 - 3 mm.	=	0 pts
3.1 – 5 mm.	=	2 pts
5.1 – 7 mm.	=	3 pts
7.1 – 9 mm.	=	4 pts
> 9 mm.	=	5 pts

Negative OJ (x-bite) 1 pt. per mm. per tooth =



OVERBITE

0 - 3 mm. 3.1 - 5 mm.	=	0 pts. 2 pts.
5.1 – 7 mm. Impinging (100%)	=	3 pts. 5 pts.
Total	=	0

ANTERIOR OPEN BITE

0 mm. (edge-to-edge), 1 pt. per tooth then 1 pt. per additional full mm. per tooth

Total



LATERAL OPEN BITE

2 pts. per mm. per tooth

Total



0

CROWDING (only one arch)

1 – 3 mm. 3.1 – 5 mm. 5.1 – 7 mm. > 7 mm.	= = =	1 pt. 2 pts. 4 pts. 7 pts.
Total	=	7

OCCLUSION

Class I to end on End on Class II or III Full Class II or III Beyond Class II or III	= = =	0 pts. 2 pts. per sidepts. 4 pts. per side8pts. 1 pt. per mm10pts. additional
Total	=	18

LINGUAL POSTERIOR X-BITE

1 pt. per tooth	Total	=		2
BUCCAL POSTERI	OR X-E	<u>BITE</u>		
2 pts. per tooth	Total	=		0
CEPHALOMETRIC	1 <u>S</u> (Se	e Instruct	ions))
ANB $\geq 6^{\circ}$ or $\leq -2^{\circ}$			=	4 pts.
Each degree $< -2^{\circ}$		_x 1 pt.	=_	6
Each degree $> 6^{\circ}$		_x 1 pt.	=_	
SN-MP				
$\geq 38^{\circ}$			=	2 pts.
Each degree $> 38^{\circ}$		_x 2 pts	. =_	
$\leq 26^{\circ}$			=	1 pt.
Each degree $< 26^{\circ}$		_x 1 pt.	=_	
1 to MP $\geq 99^{\circ}$			=	1 pt.
Each degree $> 99^{\circ}$		_x 1 pt.	=_	
	Tota	al	=	10
			L	

<u>OTHER</u> (See Instructions)

Supernumerary teeth	x 1 pt. =
Ankylosis of perm. teeth	x 2 pts. =
Anomalous morphology	x 2 pts. =
Impaction (except 3 rd molars)	x 2 pts. =
Midline discrepancy (≥3mm)	@ 2 pts. = 2
Missing teeth (except 3 rd molars)	x 1 pts. =
Missing teeth, congenital	x 2 pts. =
Spacing (4 or more, per arch)	x 2 pts. =
Spacing (Mx cent. diastema \geq 2mm)	@ 2 pts. =
Tooth transposition	x 2 pts. =
Skeletal asymmetry (nonsurgical tx)	@ 3 pts. =
Addl. treatment complexities	x 2 pts. =

Identify:

Total

=

2



4 R ١., 1 Buccal Surface 1 1 L R Lingual Surface **Occlusal Relationships** 2 R II. **Interproximal Contacts** 0 R 1 **Root Angulation** 1

1

Occlusal Contacts

INSTRUCTIONS: Place score beside each deficient tooth and enter total score for each parameter in the white box. Mark extracted teeth with "X". Second molars should be in occlusion.

IBOI Pink & White Esthetic Score

Total Score: =



1. Pink Esthetic Score





I. M & D Papillae	0	1	2
2. Keratinized Gingiva	0	1	2
3. Curvature of Gingival Margin	0	1	2
1. Level of Gingival Margin	0	1	2
5. Root Convexity (Torque)	0	1	2
5. Scar Formation	0	1	2
I. M & D Papilla	0	1	2
2. Keratinized Gingiva	0	1	2
3. Curvature of Gingival Margin	0	1	2
1. Level of Gingival Margin	0	1	2
5. Root Convexity (Torque)	0	1	2
6. Scar Formation	0	1	2

Total =

Total =

0

1

2. White Esthetic Score (for Micro-esthetics)





1. Midline 0 1 2 2. Incisor Curve 1 2 0 3. Axial Inclination (5°, 8°, 10°) 2 0 1 4. Contact Area (50%, 40%, 30%) 0 1 2 5. Tooth Proportion (1:0.8) 0 1 2 6. Tooth to Tooth Proportion 2 0 1 1. Midline (0) 1 2 2. Incisor Curve 0(1)2 3. Axial Inclination (5°, 8°, 10°) (0) 1 24. Contact Area (50%, 40%, 30%) (0) 1 2 5. Tooth Proportion (1:0.8) (0) 1 2 6. Tooth to Tooth Proportion (0) 1 2