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Effect of Corticotomy on Maxillary Anterior Bone Segment Retraction Induced by Orthopedic Force

YOSHIYASU YOSHIKAWA, NORIMASA OKAFUJI, YUJI ASHIZAWA and TOSHIO DEGUCHI
Department of Orthodontics, Matsumoto Dental College
(Chief : Prof. T. Deguchi)

Summary

The dry skulls of two adult female Japanese macaques were used in this study of bone strains produced by corticotomy combined with orthopedics. The directions and magnitudes of the principal strains were measured using an eight-pair triaxial strain gauge rosette.

While compressive strains were seen in the control study (orthopedic force alone before corticotomy), tensile strains were seen in the experimental study (orthopedic force after corticotomy) on the frontzygomatic suture, the lateral side of the zygomaticomaxillary suture of the zygomatic bone, and on the maxillary bone. Corticotomy, combined with the posterior transfer of the anterior segment, had the following effects : in the control study, traction was diffused though the maxillofacial structures, while in the experimental study, it did not readily diffuse because the compact bone was separated. This resulted in favorable conditions for the posterior transfer of the anterior maxillary segment between the maxilla proper and the maxillary alveolar bone which are connected only by trabecular bone. These results demonstrate the usefulness of combining a corticotomy with retraction of the maxillary anterior segment by orthopedic forces.

A clinical case of Class II malocclusion is presented to illustrate what can be accomplished with treatment by corticotomy. The treatment objectives were achieved with improvement in the patient's profile and in the function and esthetics of the dentition.

Introduction

Anterior maxillary osteotomy is a well-established surgical procedure for use in the correction of anterior skeletal or dental maxillary prognathism in adults. Daniel et al[1]. reported that the main advantage of the procedure is the relatively short treatment time.

The reported complications associated with the early applications of this technique included devitalization of teeth, loss of part or all of the osteotomized segment, and relapse[2]. With current techniques, however, no major problems involving the teeth, bone or soft tissue loss are reported[3], although minor complications such as devitalization still occur. Leibold et al[4]. reported that 50%

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of the non-responsive teeth were maxillary canines. The relatively high positions of their apices and their cornerstone positions in the mobilized segments apparently make the canines the teeth most vulnerable to surgical trauma.

Corticotomy was advocated by Köle[5], who reported more rapid movement of teeth since the main resistance to movement arises from cortical bone rather than from the thin trabecula of the spongiosa. Corticotomy of the maxillary and mandibular bones facilitates orthodontic displacement of the alveolar processes of a single tooth or of a group of teeth. This displacement saves time and reduces the risk of relapse. There are both experimental[6~9] and clinical[10~12] reports describing this method.

Nishimoto[13] previously performed corticotomies in conjunction with maxillary anterior bone segment retraction in Japanese macaque monkeys (*Macaca fuscata*) and conducted evaluative cephalometric, dental cast, and histopathologic studies of the related sutures. The present study was undertaken to obtain strain gauge measurements of the macaque dry skulls following the application of the technique in his study.

A clinical case of Class II malocclusion treated by corticotomy is also presented.

Materials and Methods

1. Materials

The two adult female Japanese macaque dry skulls were used in this experiment. Their dental development appears to be advanced for their chronological ages (at least 9.5 years) as determined by Kirino *et al.* (Yoshikawa[6]). Since bone is an elastic material[14], the same skull was used for both the control (before corticotomy) and experiment (after corticotomy) measurements, and the other skull was used for temperature compensation in the strain measurement procedure.

2. Anchoring of Skull

One skull was fixed with acrylic resin to a stainless steel pipe imbedded in a block of dental stone. The sagittal and occlusal planes were set vertically and horizontally, respectively (Fig. 1). The other dry skull was not anchored.

3. Strain gauge

The directions and magnitudes of the principal strains were measured with trixial rosette strain gauges (KFG-1-120-D17-11L1M2S, Kyowa Electric Instruments Co., Ltd., Tokyo, JAPAN) cemented to the bone. Prior to attachment the 16 strain gauges (Fig. 1), the surface of each skull was degreased in acetone and allowed to dry overnight in a desiccator. The gauges were cemented to the skull with a cyano-acrylate monomer adhesive (Type CC-33A, Kyowa Electronic Instruments Co., Ltd., Tokyo JAPAN). A Wheatstone bridge circuit recording device was used to measure the strains. Since a strain gauge may be affected by its own heating and the ambient temperature, a dummy strain gauge, having the same gauge factor, was cemented to the second skull. With this arrangement, the sensitivity of the gauges could be increased without being influenced by the temperature[15]. Figure 2 shows the bilateral placement of the strain gauge Pairs 1 to 8. Pair 7 was placed on the medial side of the zygomatic arch.

4. Data Processing

The strains produced by the orthopedic traction were recorded on a personal computer (PC -9801, NEC, Tokyo JAPAN) via a strain amplifier (Universal Digital Measuring System, UCAM -5B, Kyowa Electronic Instruments Co., Ltd., Tokyo JAPAN) and a scanner (Universal Scanning Box, USB-51A, Kyowa Electronic Instruments Co., Ltd., Tokyo JAPAN) which was connected to

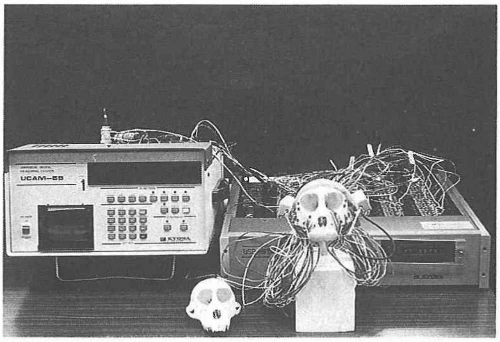

Figure 1. Testing apparatus showing skulls and recording equipment.

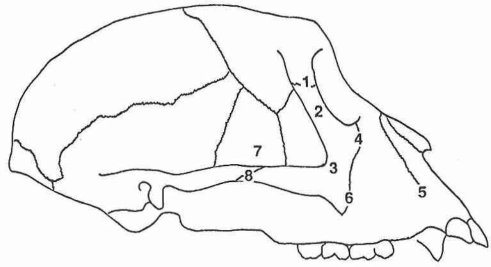

Figure 2. Strain gauge locations on the skull. Pair 7 was positioned on the medial side of the zygomatic arch.

each of the 16 gauges. The following formulae were used for the rosette analysis[16]:

Maximum principal strain

$$\varepsilon_1=\frac{1}{2}\left[\varepsilon_a+\varepsilon_c+\sqrt{2\{(\varepsilon_a-\varepsilon_b)^2+(\varepsilon_b-\varepsilon_c)^2\}}\right]$$

Minimum principal strain

$$\varepsilon_2=\frac{1}{2}\left[\varepsilon_a+\varepsilon_c-\sqrt{2\{(\varepsilon_a-\varepsilon_b)^2+(\varepsilon_b-\varepsilon_c)^2\}}\right]$$

Direction of maximum principal strain

$$\varepsilon_a>\varepsilon_c \qquad \theta=\frac{1}{2}\tan^{-1}\left(\frac{2\ \varepsilon_b-\varepsilon_a-\varepsilon_c}{\varepsilon_a-\varepsilon_c}\right)$$

$$\varepsilon_a<\varepsilon_c \qquad \theta=\frac{1}{2}\tan^{-1}\left(\frac{2\ \varepsilon_b-\varepsilon_a-\varepsilon_c}{\varepsilon_a-\varepsilon_c}\right)+90^0$$

where ε_a, ε_b, and ε_c are the output strains and θ is the direction of the maximum principal strain in the counterclockwise direction from the ε_a-axis. The direction of the minimum principal strain is perpendicular to the maximum principal strain.

5. Braces and Traction Method

An alginate impression was taken of the skull and an acrylic resin headgear, resembling a helmet, was constructed. The force module was positioned in place with the headger. Acrylic resin was then applied to fix the module. A resin splint was constructed using the same method as for the headgear (Fig. 3). In this study, micro-load cells (LTS-1 KA, Kyowa Electronic Instruments Co., Ltd., Tokyo, JAPAN) were used to accurately measure forces. A strain amplifier was used to measure forces with output readings with $\varepsilon\times10^{-6}$ equivalent strain. In the calibration record, a value which corresponds to 1×10^{-6} equivalent strain, multiplied by the reading, can be found. The desired load value was defined as (output from a strain amplifier $\times10^{-6}$)$\times$(calibration factor, $g^f/1\times10^{-6}$).

On the right side, the rated output was 3917×10^{-6} strain/1 kgf from the calibration sheet. The output from the strain amplifier was -334×10^{-6} strain when it was unloaded and 1115×10^{-6} strain when it was loaded. Thus, on the right side:

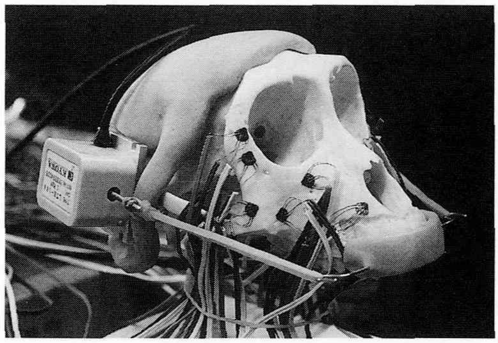

Figure 3. Testing apparatus showing loading equipment and strain gauges.

1 kgf : 3917=x : 1115−(−334)   x=370 gram.

Similarly, on the left side, the rated output was 3878×10^{-6} strain/1 kgf. The unloaded output was 68×10^{-6} strain, while the loaded reading was 1476×10^{-6} strain. Therefore, on the left side:

1 kgf : 3878=x : 1476−68   x=363 gram.

Thus, the traction forces were 370 gram on the right and 363 gram on the left at 20 degrees upward from the occlusal plane. The strain data were taken three times and averaged.

6. Corticotomy

After both maxillary first premolars were extracted, control data were obtained. Then, a corticotomy was performed in the same manner as in the previous study[13] (Fig. 4). Several 2 mm deep holes were made through the cortical bone with a # 8 round bur, and connected with a # 261 fissure bur. Then the cortical bone was cut labio-lingually along the holes. Because the Japanese macaque has a shallow palate and because space for moving the anterior bone segment was needed, some parts of the maxilla mesial to the incisive fossa were cut off. The bone at the extracted first premolars was removed to provide room for moving the anterior segment. These procedures were performed under air cooling with a three-way syringe. The experimental study was then performed to examine the effect of corticotomy.

Results

In the control study (Fig. 5), high compressive strain was found in the frontozygomatic suture (Pair 1, Table 1), but less strain was seen in the inferior region of the frontozygomatic suture (Pair 2). Along the zygomaticomaxillary suture (Pairs 4 and 6), the zygomatic bone (Pair 3), and the maxillary bone adjacent to the canine apex (Pair 5), the compressive strains were also high. The highest compressive strain was found in the medial zygomatic arch and at the temporozygomatic suture (Pair 7). Lateral to the suture (Pair 8), high compressive strain was found.

After corticotomy (Fig. 6), the strain magnitudes and directions showed obvious alteration. The compressive strains became tensile at the following locations: the frontozygomatic suture (Pair 1); the maxillary bone adjacent to the canine apex (Pair 5); the lateral aspects of the zygomatic arch suture (Pair 8). For Pair 7, the magnitude was markedly decreased.

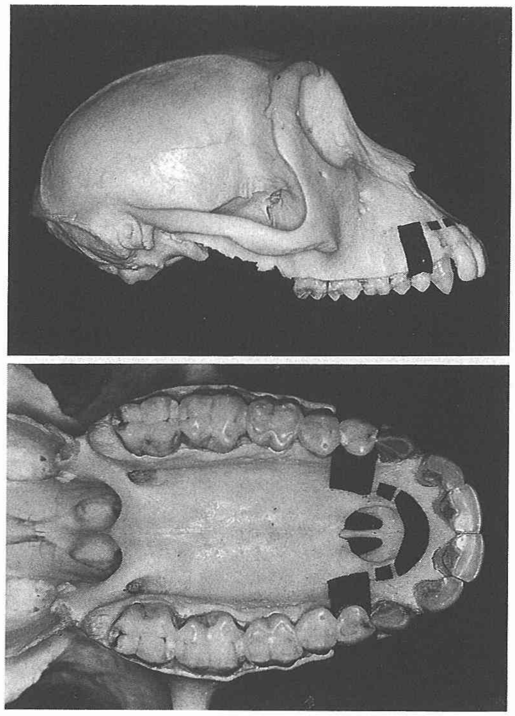

Figure 4. Region of corticotomy (buccal and lingual sides) (From Nishimoto[13])

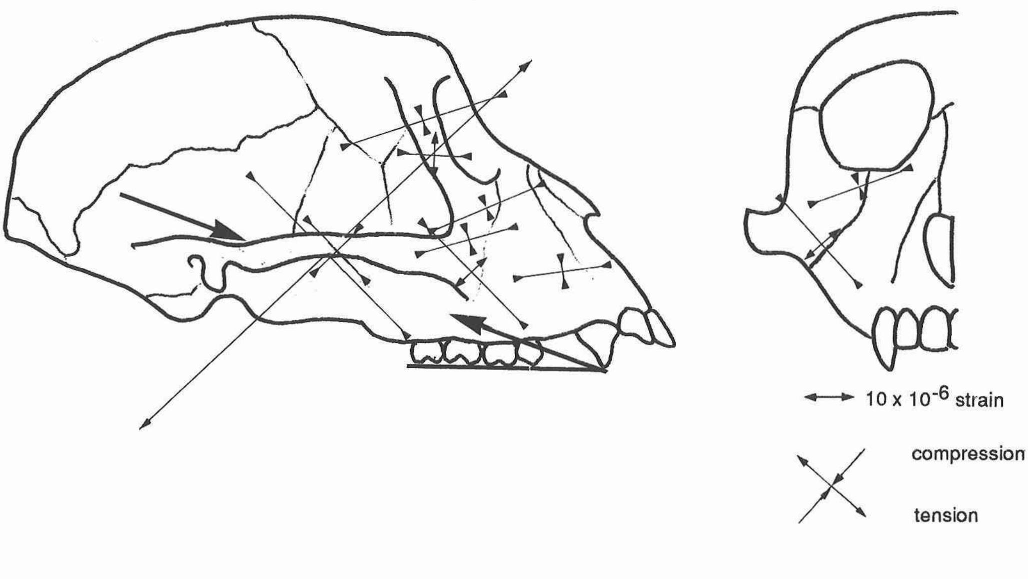

Figure 5. Strain distribution in the control skull.

Table 1. Maximum, and minimum principal strain and the direction of maximum principal strain

Gauge Pair Number	Control (before corticotomy)			Experiment (after corticotomy)		
	ε_{max}	ε_{min}	θ	ε_{max}	ε_{min}	θ
1	−3.9	−16.6	77	8.7	5.8	120
2	3.6	−7.1	131	15.5	2.0	−19
3	−3.5	−10.0	−43	11.4	−0.9	−29
4	−2.0	−11.0	−27	8.6	−5.6	−23
5	−2.4	−9.6	98	6.6	3.4	−9
6	3.7	−13.2	75	12.7	−8.2	51
7	60.7	−22.2	−24	39.8	−10.8	−33
8	−6.9	−7.6	114	11.6	3.4	−7

ε_{max}, maximum principle strain; ε_{min}, minimum principle strain; θ, direction of maximum principle strain; data with negative sign represent compression strain (X 10^{-6}) and those with positive sign represent tension strain (X 10^{-6}).

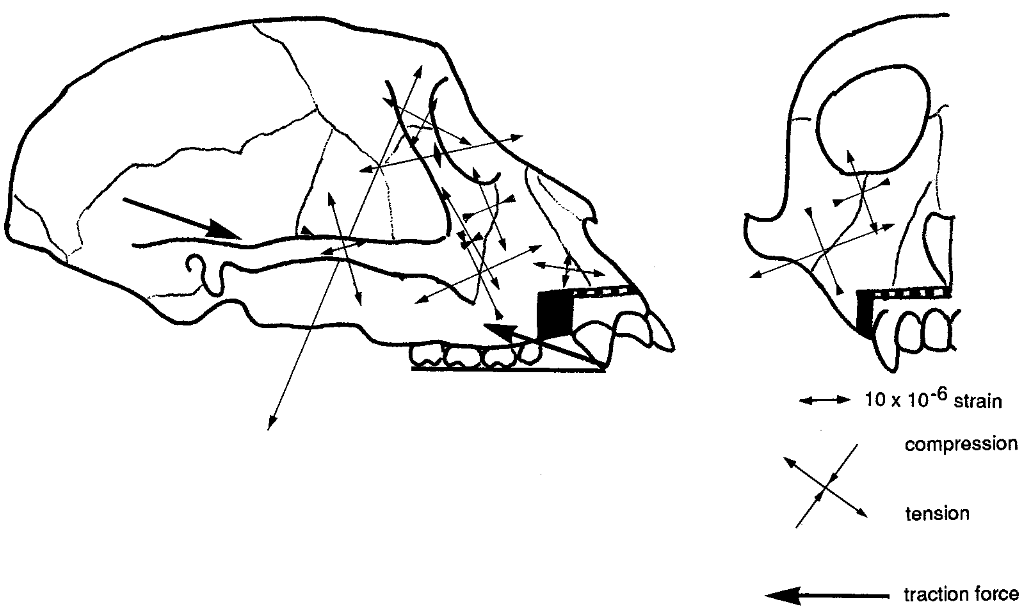

Figure 6. Strain distribution in the experimental skull.

Case Presentation

A clinical case of Class II malocclusion is presented to illustrate what can be accomplished with treatment by corticotomy.

History and general clinical background

The female patient was 34 years old at the start of treatment. Her general health was excellent and there were no conditions present that would in any way contraindicate treatment. The oral tissue appeared to be healthy and the dentition in a good state of repair, with no caries lesions present. No detrimental habits were noted. Her mother showed maxillary protrusion.

The patient's profile was protrusive and the lips strained on closure. An excessive vertical growth pattern was evident. Her overjet was 11 mm and overbite was 4 mm (Figs. 7 and 8).

Diagnosis

The occlusion was classified as Angle Class II with maxillary protrusion. There were no apparent tissue pathoses. Cephalometrically, marked protrusion of the maxillary dentures was evident. The Angle Classification was Class II with an ANB relationship of 7°. The maxillary incisors were very protrusive and forward of the bony base, as indicated by the U1 to FH position of 128° (Table 2, and Figs 8, 12). The panoramic radiograph confirmed the presence of all permanent teeth with the exception of the upper and lower right wisdom teeth (Fig. 11).

Diagnostic summary

The following clinical findings were noted: Angle Class II ; Skeletal II (ANB 7°) ; Maxillary protrusion ; and Prognathic profile with protruded lip position.

Treatment objective

Although the Wassmund-Wunderer method was considered for the initial treatment plan, it was very difficult for the patient to remain in the hospital for the extended period of time required, as she had three children. Corticotomy and orthopedic force method was chosen after consultations and obtaining informed consent. This method was selected because it is safer and requires less time in the hospital than the Wassumund-Wunderer method and because it was anticipated that the time spent wearing the head gear equipment and the total treatment period would be less than that required for conventional orthodontic treatments.

Figure 7. Pre-treatment facial photographs.

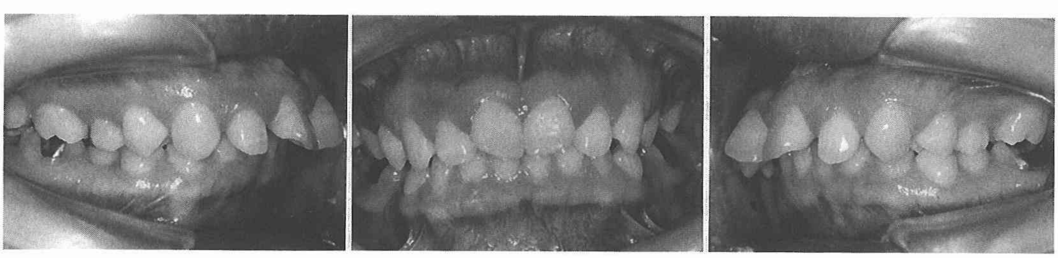

Figure 8. Pre-treatment intraoral photographs.

Table 2. Cephalometric measurements in the patient

measurement	norm	pre-treatment	post-treatment
SNA	82	89	86
SNB	79	82	78
ANB	3	7	6
IMPA	96	97	98
FMA	29	30	31
FMIA	55	53	51
U1-FH	110	128	98
U1-SN	104	127	97
Y-Axis	65	70	71
Interincisal	126	105	133
Occlusal PI	11	5	15
U-Lip to E-line	0	5	3
L-Lip to E-line	2	4	0

Treatment stages

A full-banded edgewise, Roth type of appliance with pretorqued, preangulated 0.022×0.029 inch bonded brackets was used to treat this malocclusion. The treatment stages described below were undertaken.

1. All of the teeth of both the maxillar and mandibular dentition were bonded or banded except the maxillary first premolars. Leveling of the arches and correction of rotations of each tooth were accomplished with super elastic wires. Leveling was performed by 0.017×0.025 inch stainless steel wire before corticotomy operation.
2. After application of general anesthesia, the corticotomy operation was performed in the maxilla. The Neiman incision was performed and the location of the basal margin of the piriform aperture was confirmed. The horizontal corticotomy procedure was then performed on the buccal and lingual sides for two- or three-mm width using a cross cut tapered fissure bur. The vertical corticotomy was performed at the site of the first premolars after extraction of these teeth for eight-mm width using bone chisel.

The patient used a transpalatal bar, J-hook and face bow combination head gear. During the period of use of this equipment, the extraction space was half closed within 50 days after the operation. The maxillary anterior segment was retracted.

3. One year after the operation, occlusion, interdigitation, and finishing were completed.

Progress of treatment

The patient was seen at four-week intervals during the treatment. No appliance breakage was noted; the patient's cooperation and oral hygiene were excellent at all times and her progress was satisfactory.

Treatment results

The facial esthetics improved considerably, and the occlusion and soft-tissue response were good. The maxillary protrusion-type profile was reduced as a result of the retraction of the maxillary incisors (Fig. 9 and 10). The dental occlusion and interdigitation were acceptable. Canine rise was good, with no interferences, and canine protection and anterior guidance were considered to be adequate for future protection of the dentition. The panoramic radiograph showed good approximation of the roots in the extraction sites. No root resorption was evident in either the upper or lower anterior segment (Fig. 11). The FMA angle was slightly opened (Fig. 12).

Figure 9. Post-treatment facial photographs.

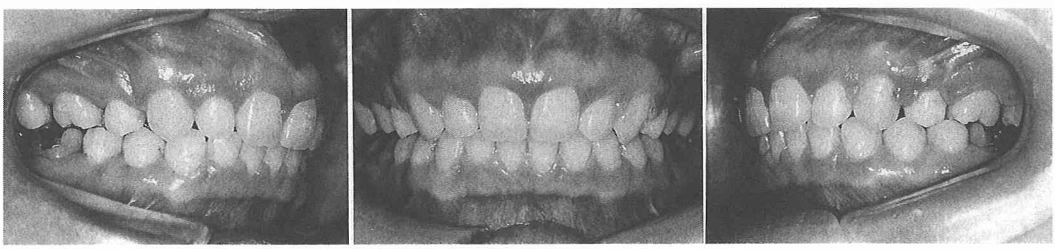

Figure 10. Post-treatment intraoral photographs.

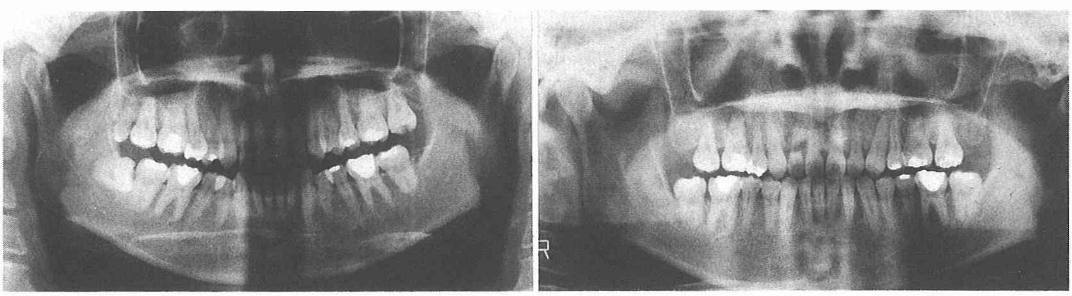

Figure 11. Panoramic radiographs. Pre-treatment (Left) and post-treatment (Right).

Secondary Treatment

All brackets and bands were removed, and the patient was instructed to wear a custom-made tooth positioner with face bow for one year during sleep. Final records were taken immediately after removal of the bands. The patient was observed monthly for the first six months. Retention time is completed and she has shown no relapse.

Final evaluation of the clinical case

We believe that, in the clinical patient with maxillary protrusion, the satisfactory occlusion, ANB change, tooth position, and facial changes justified the corticotomy and orthopedic therapy.

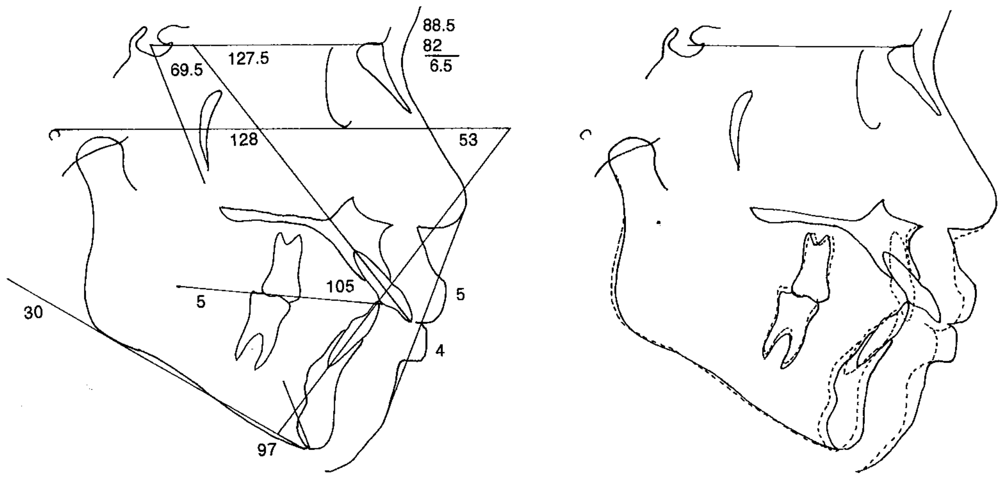

Figure 12. Tracing of cephalometric radiograph at pre-treatment (Left) and superimposition of the pre-treatment and post-treatment tracings on SN-plane registered at sella. Solid line at pre-treatment and doted line at post-treatment (Right).

The treatment objectives were achieved with improvement in the patient's profile and in the function and esthetics of the dentition.

Discussion

In the study of dynamic bone morphology, the following techniques have been used: photoelasticity[17,18], stress coat[19,20], holography interference[21,22], and measurement with strain gauges[6,15,21~27]. The strain gauge method has provided excellent results in elucidating medical and dental biomechanics. Nakanishi[15], Suzuki[16], and Shirai[23] performed triaxial strain gauge experiments to analyze the deformations of the maxillary complex under orthodontic and orthopedic loads. Similarly, Fukui[24] and Hata[25] studied the orthodontic and orthopedic effects induced by a chin cup appliance, and Hylander[26,27] tested competing hypotheses by means of strain gauges. However, in few studies have corticotomies been investigated with strain gauges[6,7]. Yoshikawa[6] reported that strain values were decreased at all suture sites after corticotomy, but vertical strains could not be measured because single strain gauges were used.

Compressive strains were noted in our control study (before corticotomy), in opposition to the tensile strains observed in the experimental study (after corticotomy), for the frontozygomatic suture, the zygomaticomaxillary suture of the zygomatic bone, and on the maxillary bone. The greatest tensile and compressive strains in the control study were found in the zygomatic arch suture (Pair 7), and the lateral aspect of that suture (Pair 8) showed high compressive strain. These results conflict with those of previous studies.

Suzuki[16] found that the curvature of the temporal part of the zygomatic arch was increased by backward traction force. This implies that there are tensile strains on the lateral side of the zygomatic arch and compressive strains on the medial side of the arch[6,16]. The zygomatic arch and temporozygomatic suture demonstrated the highest strains but these strains were absorbed by increased curvature of the zygomatic arch[6,16]. In contrast, the present results suggest that there is a large tensile strain on the medial side of the zygomatic arch (Pair 7) but small compressive strains on the lateral side of the zygomatic arch (Pair 8) in control skull. In experimental skull, the strain readings showed decreased tension on the medial side of the zygomatic arch (Pair 7), however, the pattern is the same as the control skull. These data indicate the tendency for the curvature of the temporal part of zygomatic arch to increase in experimental skull (after corticotomy). This can be attributed to the smaller appliance (covered only anterior segment) used in this study than the other studies (covered all maxillar).

Nishimoto[13], in a study of the histopathological changes following the application of the same procedure in living animals, found enlargement of the suture spaces in both the control (no corticotomy) and, to a lesser extent, in the experimental (with corticotomy) animal. Similar results were obtained by Droschl[28] who studied the effect of heavy continuous orthopedic forces on young squirrel monkeys. He found vigorous cell activity in the sutures after one month, when the width of the sutures had enlarged two-to three-fold. Elder and Tuenge[29] reported the effects of high-pull force application on the sutures in Rhesus monkeys. They found, in contrast to our results for the suture surfaces, that bone resorption occurred at the zygomaticomaxillary and zygomaticotemporal sutures. When heavy loads were placed on the monkey skulls, the sutures demonstrated immediate high strains. After corticotomy, these strains were decreased. In living animals, expanded sutures were noted 30—70 days later.

Corticotomy, combined with the posterior transfer of the anterior segment, seemed to have the following effects: in the control study (before corticotomy), traction was diffused through the maxillofacial structures via the sutures, while in the experimental study (after corticotomy), the traction did not diffuse as readily because the compact bone was separated. This results in favorable conditions for the posterior transfer of the anterior maxillary segment between the maxilla proper and the maxillary alveolar bone, which are connected only by trabecular bone. These results demonstrate the usefulness of combining a corticotomy with orthopedic retraction of the maxillary anterior segment.

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抄録：顎整形力を用いた上顎骨前方歯槽部の後方移動時におけるコルチコトミーの効果に関する研究

吉川仁育，岡藤範正，芦澤雄二，出口敏雄（松本歯大・歯科矯正）

2個のメス成猿ニホンザルの乾燥頭蓋骨を用いて，コルチコトミーと顎整形力を併用した上顎骨前方歯槽部の後方移動時の骨ひずみに関する研究を行った．骨ひずみの力と方向の測定は，8個の三軸ストレンゲージを用いて行った．その結果，対照では頬骨前頭縫合，頬骨の頬骨上顎縫合の外側面，および上顎骨上においては，圧縮ひずみを認めたのに対して，コルチコトミーを併用した実験において，引っ張りひずみへと逆転する現象がみられた．すなわち，上顎骨前方歯槽部の後方移動時におけるコルチコトミーの効果は次のように考えられた．前方部のコルチコトミーを併用しない対照においては，牽引力が各々の縫合部を介して伝達することによって顎顔面に拡散している．これに対してコルチコトミーを併用した実験では緻密骨が切断されているために，対照と比較して，この牽引力が拡散しにくくなり，海綿骨のみでつながっている上顎骨と上顎骨の固有歯槽骨との間において上顎前方歯槽部を後方移動させる力として有効に作用するものと考えられた．また，本法を応用して良好な顔貌，咬合を得たアングルII級不正咬合の治験例をあわせて報告した．