Bone changes after bilateral sagittal split osteotomy for mandibular prognathism

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ABSTRACT

Purpose : The purpose of this research was to study bone changes after bilateral sagittal split osteotomy through fractal analysis and measurement of mandibular cortical thickness.

Materials and Methods : This study included twenty-two prognathic patients who underwent bilateral sagittal split osteotomy. Panoramic radiographs of these patients were taken immediately before operation and at 1 month, 6 months, and 12 months postoperatively. The fractal dimension was measured by the box-counting method in the region of interest centered on both the basal and interdental bones between the first and second mandibular molars. Measurements of mandibular cortical thickness were taken both in the area between the first and second mandibular molars and at the osteotomy site. Changes of fractal dimension and cortical thickness over four stages were statistically analyzed.

Results : The fractal dimension of the mandibular basal bone before surgery and after 1 month, 6 months and 12 months were 1.4099±0.0657, 1.382±0.0595, 1.2995±0.0949, and 1.4166±0.0676, respectively (Repeated-measures ANOVA, $P<0.001$). However, no statistically significant differences were noted in interdental fractal dimensions among the four stages. Mandibular cortical thickness between the first and second mandibular molars before operation and after 1 month, 6 months and 12 months was 3.74±0.48 mm, 3.63±0.47 mm, 3.41±0.61 mm and 3.55±0.66 mm ($P<0.01$), respectively. Mandibular cortical thickness at the osteotomy site at each of the four stages was 3.22±0.44 mm, 2.87±0.59 mm, 2.37±0.61 mm and 2.64±0.62 mm, respectively ($P<0.001$).

Conclusion : This study suggests that the mandibular tissue continued decreasing for 6 months postoperatively and then increased over the subsequent 6 months. ***(Korean J Oral Maxillofac Radiol 2006; 36 : 183-8)***

KEY WORDS : Mandible; Prognathism; Osteotomy; Fractals

Introduction

Bilateral sagittal split osteotomy is commonly used to correct jaw deformities such as mandibular prognathism.[1,2] Trauner and Obwegeser popularized this technique in 1957 to correct prognathism and retrognathism. One of the great advantages of this osteotomy is that the large area of bone contact facilitates osseous union.[3-5]

To assess bone healing, histologic evaluation, biomechanical testing, bone densitometry and radiographic analysis were usually used.[6,7] Histology is a basic method for evaluating bone healing. Ellis et al.[4] performed a histologic study of the osseous healing of a sagittal ramus osteotomy and reported that the osteotomy sites showed different patterns of osseous healing according to the fixation's rigidity. Although mechanical testing such as bending, tension and torsional tests is a useful tool in evaluating fracture healing, it is a destructive method and does not offer monitoring capabilities.[6,7] Densitometry yields important information on the healing of bone. Bone densitometry such as dual-energy X-ray absorptiometry (DXA) and quantitative computed tomography (QCT) is the method of choice for defining bone mineral content[8]. However, bone densitometry requires exposing the patient to ionizing radiation. Radiographs are considered one of the simplest ways to evaluate the bone healing. Kallela et al.[5] studied radiographical osteotomy healing and reported that all osteotomies were assessed as having united in three months and that the osteotomy lines were no longer evident on radiographs after one year. Using radiographs to evaluate bone healing has the severe shortcoming that it is largely dependent on the observer's subjective interpretation.[6] However, the development of digital image-processing techniques such as fractal analysis have made the procedure more objective and accurate.[9-12]

Fractal analysis is a mathematical techniques that can aid in the quantification of complex structures.[13] The structure of the

Received October 9, 2006; accepted November 14, 2006
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trabecular bone is fractal in nature and any trabecular changes can result in changes in the fractal dimensions. Considering that fractal analysis is independent of such variables as projection geometry, alignment and radiodensity,[14-17] it can provide a diagnostic tool for objectively characterizing trabecular bone structures. Many investigators have evaluated the structure of the trabecular bone by fractal dimension in order to distinguish individuals with osteoporosis from those without osteoporosis.[18-20] In addition, Heo et al.[21] reported that fractal dimension could be used to evaluate the bone healing process after orthognathic surgery.

Mandibular cortical thickness is also a popular index for assessing bone changes because it requires no specialized facilities. Many radiographic studies have shown a reduction in cortical thickness on the gonion in older females.[22-25] Also, Horner et al.[26] reported that inferior mandibular cortical thickness was directly related to mandibular bone mineral density.

After mandibular setback surgery, the mandible undergoes drastic environmental changes such as vascularities, muscle orientation and mastication, and is affected by these changes. There have been relatively few studies on the bone changes after bilateral sagittal split osteotomy. This paper aims to evaluate bone changes after bilateral sagittal split osteotomy through fractal analysis and measurement of mandibular cortical thickness.

Materials and Methods

The subjects consisted of twenty-two patients (11 women and 11 men) who underwent bilateral sagittal split osteotomy at Pusan National University Hospital between 2001 and 2004. The patients' mean age was 22.14±2.83 years (range, 19 to 31 years). All of the patients underwent presurgical and postsurgical orthodontic treatment. A criterion for inclusion in the study was the availability of panoramic radiographs with adequate quality and resolution. Four panoramic radiographs were obtained from each patient, immediately before surgery and at 1 month, 6 months and 12 months after surgery using 2002 CC Proline (Planmeca Co., Helsinki, Finland).

For fractal analysis, the panoramic radiographs were digitized at 400 dpi with 256 gray levels by using an Umax Astra 4000 U scanner (UMAX Technologies, Dallas, TX, USA). Using Photoshop 7.0 (Adobe Systems Inc., San Jose, CA, USA), we selected 70×70 and 50×50 pixel-sized regions of interests (ROIs) on both the basal and interdental bones between the first and second mandibular molars, respectively (Fig. 1). When creating ROIs, great care was devoted to exclude the lamina dura, periodontal ligament space, cortical bone or any other anatomical structures which would affect the trabecular pattern. To create the binary images, we used the method described by White and Rudolph.[10] The fractal dimension was calculated using the box counting method with the Image J software program (1.34s, National Institutes of Health, Bethesda, USA).

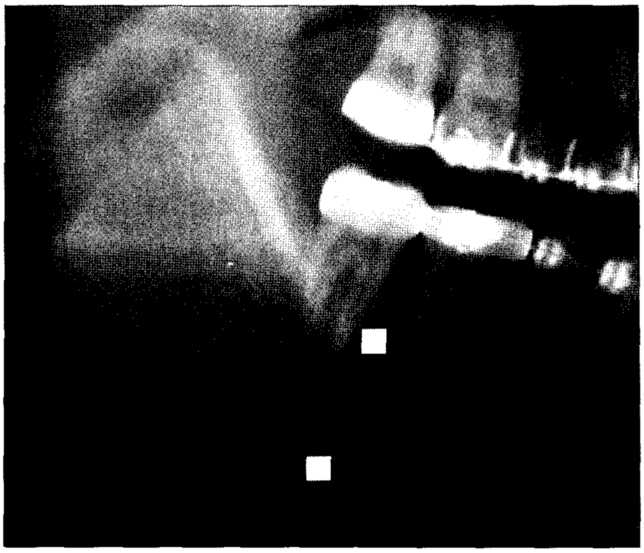

Fig. 1. Region of interest was centered at both the basal and interdental bones between the first and second mandibular molars.

Mandibular cortical thickness was measured at two sites; one between the first and second mandibular molars and the other at the osteotomy site. The inferior edge of the mandible was traced and a line tangential to its inferior border was drawn. A line was constructed perpendicular to this tangent line intersecting the inferior border between the first and second mandibular molars and at the osteotomy site. Mandibular cortical thickness was measured along this line.[18] The measurements were estimated within 0.1 mm. The measurements were corrected by the magnification factor provided by the manufacturer of the panoramic machine. Mandibular cortical thickness was measured by two viewers with advanced training in oral and maxillofacial radiology and interobserver reproducibility was assessed. To determine intraobserver reproducibility, one observer repeated the measurements twice at an interval of four weeks.

Statistical Analysis

The inter and intraobserver reproducibilities of the measurements of mandibular cortical thickness were assessed using coefficients of variation[27]; they were 2.998% for interobserver reproducibility and 2.043% for intraobserver reproducibility.

The differences of fractal dimensions and mandibular cortical thickness among the stages were analyzed using the repeated-measures analysis of variance (ANOVA). An independent sample t test was used to examine the differences between males and females, between genioplasty and non-genioplasty and between setback less than and more than 10 mm. A P value less than 0.05 was considered a statistically significant difference. All the statistical procedures were performed with SPSS (Ver 12.0 for windows, Chicago, IL, USA).

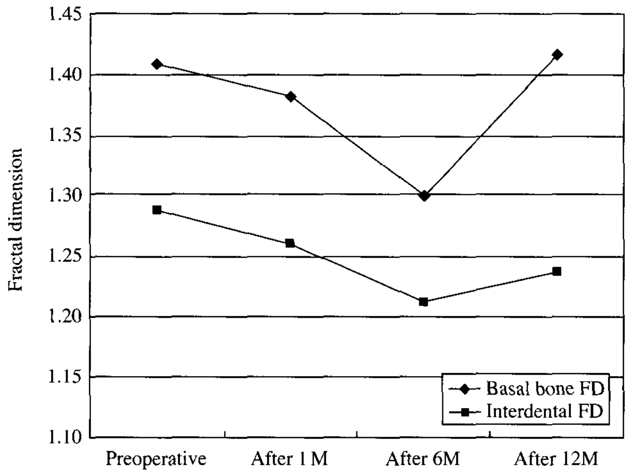

Fig. 2. Changes in fractal dimension.

Results

Fig. 2 shows that the fractal dimension gradually decreased for 6 months postoperatively and subsequently increased over the remaining 6 months of the year. For fractal dimension, statistically significant differences among stages were shown not for the interdental bone but for the mandibular basal bone (Repeated-measures ANOVA, $P<0.001$) (Table 1, 2). Also, no significant differences in fractal dimension were found for any of the three variables of gender, genioplasty, or amount of setback.

The postoperative changes in mandibular cortical thickness are shown in Fig. 3. Mandibular cortical thickness showed statistically significant differences at both sites among stages, between the first molar and second mandibular molars as well as osteotomy site (Table 3, 4). No significant differences in mandibular cortical thickness were found by gender, genioplasty, or amount of setback.

Table 1. Changes in fractal dimension of the mandibular basal bone

Variables	N	Preoperative	After 1 month	After 6 months	After 12 months
Gender					
Male	11	1.4188±0.0734	1.4030±0.0452	1.2973±0.1003	1.4193±0.0693
Female	11	1.4009±0.0591	1.3610±0.0664	1.3017±0.0941	1.4138±0.0692
Genioplasty					
With genioplasty	10	1.4124±0.0725	1.3712±0.0764	1.2483±0.1013	1.4232±0.0794
Without genioplasty	12	1.4078±0.0627	1.3910±0.0421	1.3422±0.0665	1.4110±0.0591
Setback					
Less than 10 mm	12	1.4195±0.0476	1.3620±0.0628	1.2951±0.0935	1.4343±0.0712
More than 10 mm	10	1.3983±0.0838	1.4060±0.0475	1.3048±0.1014	1.3953±0.0597
Total patients	22	1.4099±0.0657	1.3820±0.0595	1.2995±0.0949	1.4166±0.0676*

* $P<0.001$ (Repeated-measures ANOVA)

Table 2. Changes in fractal dimension of the interdental bone

Variables	N	Preoperative	After 1 month	After 6 months	After 12 months
Gender					
Male	11	1.3164±0.1403	1.2905±0.0624	1.1996±0.2414	1.2849±0.1072
Female	11	1.2591±0.1056	1.2287±0.1690	1.2233±0.1429	1.1880±0.1458
Genioplasty					
With genioplasty	10	1.2790±0.1583	1.2271±0.1353	1.2102±0.1503	1.2106±0.1350
Without genioplasty	12	1.2951±0.0952	1.2867±0.1211	1.2126±0.2309	1.2580±0.1358
Setback					
Less than 10 mm	12	1.2776±0.1158	1.2250±0.1559	1.2244±0.1312	1.1796±0.1404
More than 10 mm	10	1.2999±0.1400	1.3011±0.0718	1.1960±0.2574	1.3047±0.0925
Total patients	22	1.2878±0.1247	1.2596±0.1283	1.2115±0.1939	1.2364±0.1344

Table 3. Changes in mandibular cortical thickness of the area between the first molar and second mandibular molars

Variables	N	Preoperative	After 1 month	After 6 months	After 12 months
Gender					
Male	11	3.78±0.47	3.65±0.48	3.50±0.48	3.68±0.47
Female	11	3.70±0.51	3.61±0.49	3.33±0.74	3.41±0.81
Genioplasty					
With genioplasty	10	3.87±0.51	3.75±0.51	3.49±0.77	3.63±0.87
Without genioplasty	12	3.64±0.45	3.53±0.44	3.35±0.47	3.47±0.45
Setback					
Less than 10 mm	12	3.88±0.40	3.76±0.41	3.44±0.69	3.60±0.78
More than 10 mm	10	3.58±0.54	3.48±0.53	3.38±0.54	3.48±0.53
Total patients	22	3.74±0.48	3.63±0.47	3.41±0.61	3.55±0.66*

* Repeated measures ANOVA, $P<0.01$

Table 4. Changes in mandibular cortical thickness of osteotomy sites

Variables	N	Preoperative	After 1 month	After 6 months	After 12 months
Gender					
Male	11	3.27±0.40	3.02±0.42	2.57±0.46	2.83±0.41
Female	11	3.18±0.49	2.71±0.71	2.17±0.69	2.46±0.75
Genioplasty					
With genioplasty	10	3.22± 0.50	2.90±0.56	2.38±0.74	2.63±0.77
Without genioplasty	12	3.23±0.41	2.84±0.63	2.36±0.51	2.65±0.50
Setback					
Less than 10mm	12	3.26±0.40	2.93±0.48	2.37±0.67	2.65±0.70
More than 10mm	10	3.18±0.50	2.79±0.72	2.38±0.56	2.64±0.55
Total patients	22	3.22±0.44	2.87±0.59	2.37±0.61	2.64±0.62*

* Repeated measures ANOVA, $P<0.001$

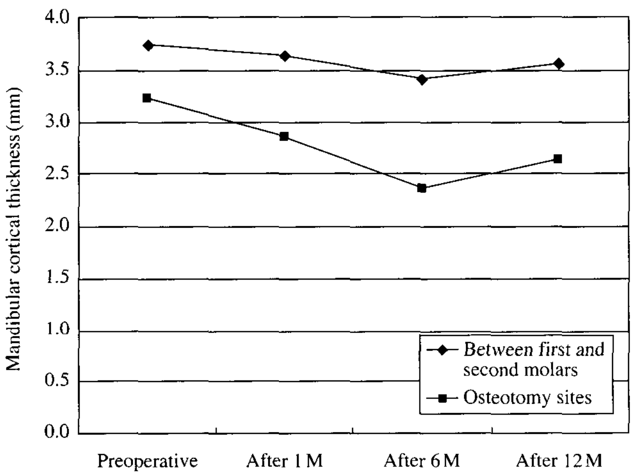

Fig. 3. Changes in Mandibular cortical thickness.

Table 5. Probability values of fractal dimension and mandibular cortical thickness between stages

			After 1 month	After 6 months	After 12 months
Fractal dimension	Basal bone	Preoperative	0.075	0.000	0.702
		After 1 month		0.001	0.07
		After 6 months			0.000
	Interdental bone	Preoperative	0.341	0.104	0.057
		After 1 month		0.298	0.439
		After 6 months			0.571
Mandibular cortical thickness	Between first and second molars	Preoperative	0.000	0.000	0.012
		After 1 month		0.002	0.289
		After 6 months			0.000
	Osteotomy sites	Preoperative	0.000	0.000	0.000
		After 1 month		0.000	0.005
		After 6 months			0.000

Table 5 shows the probability values between stages. The fractal dimension of the basal bone six months after surgery was significantly different from that of all the other stages ($P<0.01$). Most of the mandibular cortical thicknesses showed significant differences between stages.

Discussion

Bilateral sagittal split osteotomy is one of the most popular operations for management of mandibular prognathism. This technique allows for a wide bone contact that results in a quick bone union. Usually, the healing process after osteotomy is evaluated by follow-up radiographs. When evaluating bone changes, fractal dimension and mandibular cortical thickness are very useful because of their non-invasiveness and convenience.

In this study, the overall results for fractal dimension and mandibular cortical thickness showed a similar pattern in that both decreased for six months after surgery and increased after that.

The fractal dimension of the basal bone showed distinct changes over the four stages. It fell to a significantly low level at postoperative 6 months compared with those of the other stages and then ascended to the presurgical level by 12 months. We conjecture that the trabecular bones were resorbed after surgery and then started to reform as healing proceeded and masticatory function recovered normally. However, the fractal dimension of the interdental area showed no statistically significant difference before and after surgery and did not recover its presurgical level at postoperative 12 months. This might be because this area is surrounded by teeth and is less influenced by local environmental changes than basal bones.

This study is the first to measure the changes in mandibular cortical thickness after bilateral sagittal split osteotomy. The study showed that mandibular cortical thickness varied from stage to stage. Apart from the results for the fractal dimension, which showed no statistically significant difference between preoperatively and 1 month postoperatively, the cortices became significantly thinner at postoperative 1 month compared with the preoperative thickness. From this result, we presume that endosteal resorption was more prompt than the trabecular bone resorption. Even though the cortices began to thicken six months after surgery, they never recovered their original thicknesses in 12 months. We suppose the reason that the cortices did not regain their preoperative level by 12 months might not be because of insufficient follow-up time. We set the evaluation time to one year based on the studies of Kallela et al.[5] and Heo et al.,[21] which showed full postoperative recovery in one year. Moreover, when we measured the cortical thicknesses, the smooth continuous cortical lines between segments confirmed that all of the cortices had remodelled at postoperative 12 months. Normally, the mandibular cortex thins as it approaches the gonion. When the osteotomy was performed, the overlapping two segments had the different cortical thicknesses. During the process of union, the thicker cortex of the anterior segment was resorbed, remodelled and its integrity was recovered to that of the posterior segment. This could be the reason that the cortical thickness did not regain its preoperative level.

This study showed no statistically significant differences in the variables of gender, genioplasty or the amount of setback. The elapsed time was the main factor that influenced the postoperative bone changes.

In conclusion, we suppose that there would be drastic bone changes after osteotomy and that they are measurable through fractal dimension and mandibular cortical thickness. This paper showed that the mandibular bone continued to be resorbed for 6 months after surgery and then to be regained over the subsequent 6 months.

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