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Dental stability and radiographic healing patterns after mandibular symphysis widening with distraction osteogenesis

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SUMMARY Distraction osteogenesis is the biological process of new bone formation between bone segments that are gradually separated by incremental traction. The purpose of this study was to assess dental stability and radiographic healing patterns following mandibular symphysis widening with distraction osteogenesis (MSDO) in 19 non-syndromic patients (10 males, 9 females: mean age at the time of surgery 20 years 11 months). To evaluate dental stability, 13 landmarks were measured on the study models of all patients and healing patterns were classified for 11 subjects according to healing times on periapical or occlusal radiographs at three time points: pre-distraction (T1), post-distraction (T2), and follow-up (T3; average 1 year 6 months). Paired *t*-tests were used to evaluate the change between T2–T1, T3–T2, and T3–T1.

The results of this study showed that although there was a decrease in expansion during treatment, the total amount of surgical expansion was maintained. Arch length was significantly increased and irregularity was significantly decreased (both $P < 0.001$). There was evidence of mineralization of the distraction gap in 11 patients within 3 weeks of the end of activation. Radiographically, healing patterns for the distraction gap were diverse, but radiopacity increased over time.

MSDO is dentally stable and the distracted gap is mineralized with time, indicating that MSDO is an efficient and stable treatment method in subjects with skeletal mandibular transverse deficiency.

Introduction

Skeletal mandibular transverse deficiency is a common clinical problem, but compared with maxillary deficiency, it has received little attention, and treatment is difficult (Haas, 1965; Wertz and Dreskin, 1977; Mew, 1983; Del Santo *et al.*, 2000).

The clinical indicators of mandibular transverse deficiency are a moderate to mild decrease in mandibular arch length, a narrow intercanine width, crowding of the lower anterior teeth, a flattened anterior arch morphology, an increased overbite, and a posterior buccal crossbite (Jacobs *et al.*, 1980; Del Santo *et al.*, 2000). The treatment options include compensating orthodontics, functional appliances, and orthopaedic devices (Guerrero *et al.*, 1997). In growing patients, a transverse mandibular deficiency is commonly corrected by orthodontic expansion, lip bumpers, Schwarz devices, or functional appliances (Bell *et al.*, 1997; Davidovich *et al.*, 1997). These therapies show relatively stable results in younger patients, particularly those with lingually tipped teeth that need to be decompensated. In adults, the problems are resolved by extraction or non-extraction therapy. However, the disadvantages of such treatment in correcting the transverse discrepancy are instability, a compromised periodontium created by moving teeth out of their supporting alveolar bone, and compromised facial aesthetics. The stability of non-extraction therapy does not differ significantly from that of extraction therapy. However, if the intercanine dimension is expanded, permanent retention is required to ensure long-term post-treatment stability (Del Santo *et al.*, 2002).

In adult patients, mandibular symphysis widening with distraction osteogenesis (MSDO) with expansion has been introduced to correct mandibular transverse discrepancy, similar to osteotomies for surgical correction of maxillary transverse discrepancies (Bell, 1992). However, such osteotomies have not been used frequently in the mandibular arch because of the lack of a midsagittal suture, the significant risk of periodontal and tooth damage, the limitation of adequate rigid fixation, and the necessity for grafts.

With the introduction of a surgical technique in symphysis widening of the mandible (Bell *et al.*, 1997), mandibular transverse deficiency has been treated by gradual osteodistraction.

Distraction osteogenesis (DO) is the biologic process of new bone formation between bone segments that are gradually separated by incremental traction (Ilizarov, 1989). Guerrero (1990) used mandibular widening to correct mandibular transverse discrepancy. With the use of mandibular symphysis widening, the intercanine width can be increased predictably, and as a result the treatment modality improves aesthetics and function, shortens treatment time, and is stable.

However, problems such as tipping of the teeth and segments, loosening of the device, and more dental expansion in relation to skeletal widening still exist. For correct

treatment, it is important to understand the short- and long-term positional changes of the dento-osseous segments produced by expansion devices.

The purpose of this study was to assess dental stability and radiographic healing patterns of symphysis widening in non-syndromic patients.

Subjects and methods

The records were obtained retrospectively of 19 patients [10 males (52.67 per cent) and 9 females (47.37 per cent)], who had undergone MSDO in the dental hospital of Wonkwang University. The mean age of the subjects at the time of the surgery was 20 years 11 months (range, 7 years 7 months to 33 years 1 month). Records were obtained at pre-distraction (T1), post-distraction (T2) an average of 83 days (range, 29–210 days), and long-term follow-up (T3) an average of 1 year 6 months (range, 6–37 months) after surgery (Figure 1). The patients were treated using a symphysis osteotomy, mandibular expansion, and subsequent non-extraction orthodontic treatment. Due to the retrospective nature of this study, not all records of all subjects were available for all periods. Changes between periods were evaluated based on the maximum number of records available.

An intraoral tooth-borne Hyrax® (Dentaurum, Ispringen, Germany) was used in 17 subjects and a hybrid type (Hyrax®II) in two patients as the osteodistraction appliance to gradually widen the anterior part of the mandible. The device was placed in 17 patients using a conventional band on the first premolar and first molar or with resin (Z100™, 3M Dental Products, St. Paul, Minnesota, USA) before surgery. In the two patients with the hybrid type devices, they were placed using a screw and band on bone and canine, respectively, during surgery (after making a osteotomy line).

All the MSDO procedures were performed under local anaesthesia by two oral and maxillofacial surgeons in the dental hospital of Wonkwang University. In order to access the osteotomy site, a horizontal incision was made above the mandibular vestibule. After the flaps were raised and reflected, a vertical or stepwise groove in the labial cortical plate was made with a 701 bur according to a planned osteotomy line. The section was made from the inferior portion of the mental symphysis to 2–3 mm below the root apex with a reciprocating saw. A spatula osteotome with light tapping pressure was used to complete the surgical cut into the partially sectioned interdental osteotomy site.

A vertical interdental osteotomy was made between the central incisors in 14 patients and between the lateral incisors and canine teeth in one patient. In four patients, a stepwise osteotomy was carried out. Before suturing, the expansion device was activated three or four turns in order to secure the osteotomy and unobstructed split. After an average latency period of 6 days (range, 0–10 days), the distraction device was activated 0.75–1.00 mm per day by the orthodontist. Based on the number of turns recorded, the device was expanded 6 mm, which included the immediate post-surgical expansion. After expansion was complete, acrylic resin was applied over the Hyrax screw for stabilization and the device was maintained in place for 83 days (range, 29–210 days). Orthodontic tooth movement was started after radiographic evidence of bone healing was seen. In one patient, only an acrylic space maintainer was placed instead of a fixed appliance. Approximately one-third of the patients still had the orthodontic appliances *in situ* at the long-term follow-up.

Model examination

Thirteen landmarks were identified, marked, and measured on the study models with digital callipers (accurate to two decimal places). The distances are shown in Figure 2, arch length in Figure 3 (Shapiro, 1974), and irregularity index in Figure 4 (Little, 1975).

Radiographic examination

Due to the retrospective nature of this study, the same radiographs were not available for all subjects. Using images of periapical or occlusal views, the healing patterns of 11 patients were classified. Each bone was characterized by the length of the regenerated bone from each host bone margin, as well as the length of the radiolucent interzone relative to the length of the distraction gap; the width of the regenerated bone relative to the width of the host bone margin; the shape and density of the regenerated bone and the radiolucent interzone; and the presence or absence of corticalization (Samchukov *et al.*, 2001; Figure 5).

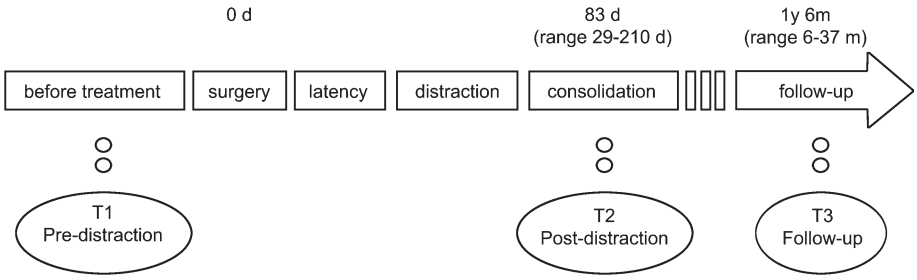

Figure 1 Time frame of distraction osteogenesis, observation, and record. (d, day; m, month; y, year).

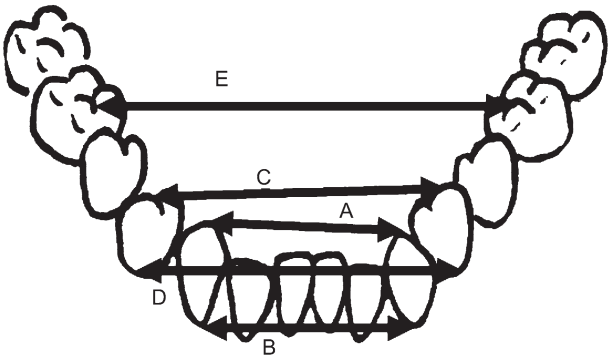

Figure 2 (A) Intercanine width 1 (distance between the cusp tips of the canines). (B) Intercanine width 2 (distance between the cervix of the canines). (C) Interfirst premolar width 1 (distance between the buccal cusp tips of the first premolars). (D) Interfirst premolar width 2 (distance between the cervix of the first premolars). (E) Interfirst molar width (distance between the mesiobuccal cusp tips of the molars).

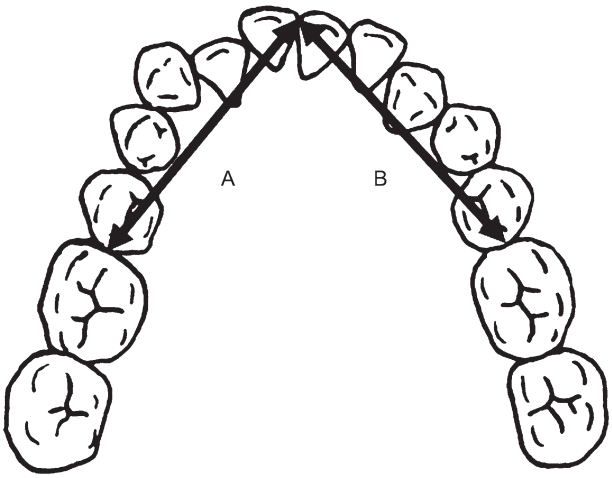

Figure 3 Arch length = A + B (sum of the right and left distances from the mesial anatomic contact points of the mandibular first permanent molars to the contact point of the central incisors or to the midpoint between the central incisor contacts, if spaced).

According to the regeneration pattern, MSDO of the 11 patients was classified into 11 types (Samchukov *et al.*, 2001; Figure 6).

Statistical analysis

All the data were assessed by one author (YWC) on two occasions with a 2-week interval between assessments and transferred to the Statistical Package for Social Sciences (SPSS Inc., Chicago, Illinois, USA) version 10.0 for windows for analysis.

Normal distributions were verified for each variable. Paired *t*-tests were performed to evaluate the amount of change between T2–T1, T3–T2, and T3–T1.

The method error (ME) of the double registrations (measurements from T1, T2, and T3) of all subjects was calculated using Dahlberg (1940), formula:

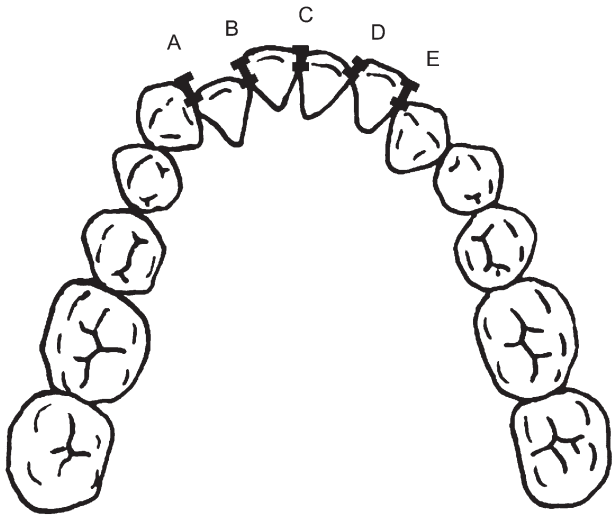

Figure 4 Incisor irregularity index = A + B + C + D + E (summed displacement of the anatomic contact points of the mandibular anterior teeth).

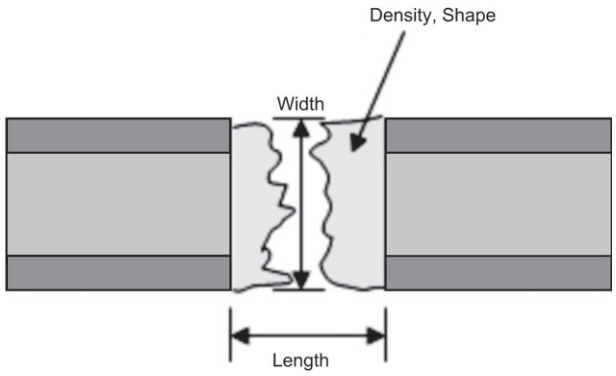

Figure 5 Distraction regenerate measurement parameters.

$$ME = \sqrt{\frac{\sum d^2}{2n}}$$

where d is the difference between two measurements of a pair and n is the number of subjects. The maximum ME for dental changes was 0.44 mm (interfirst molar width at T1) and the minimum 0.04 mm (intercanine width 2 at T2).

Results

Dental stability (n = 19 patients)

Interdental width change during the consolidation period (T1–T2). The amount of pure expansion was significantly increased by DO ($P < 0.001$). The antero-posterior view showed that the widths increased steadily from 3.0 (±2.04) mm at the first molar to 4.5 (±1.64) mm at the canine. Vertically, the widths of the cusp tips were greater than the widths of the cementoenamel junction (CEJ) of both the canine and first premolar (Table 1).

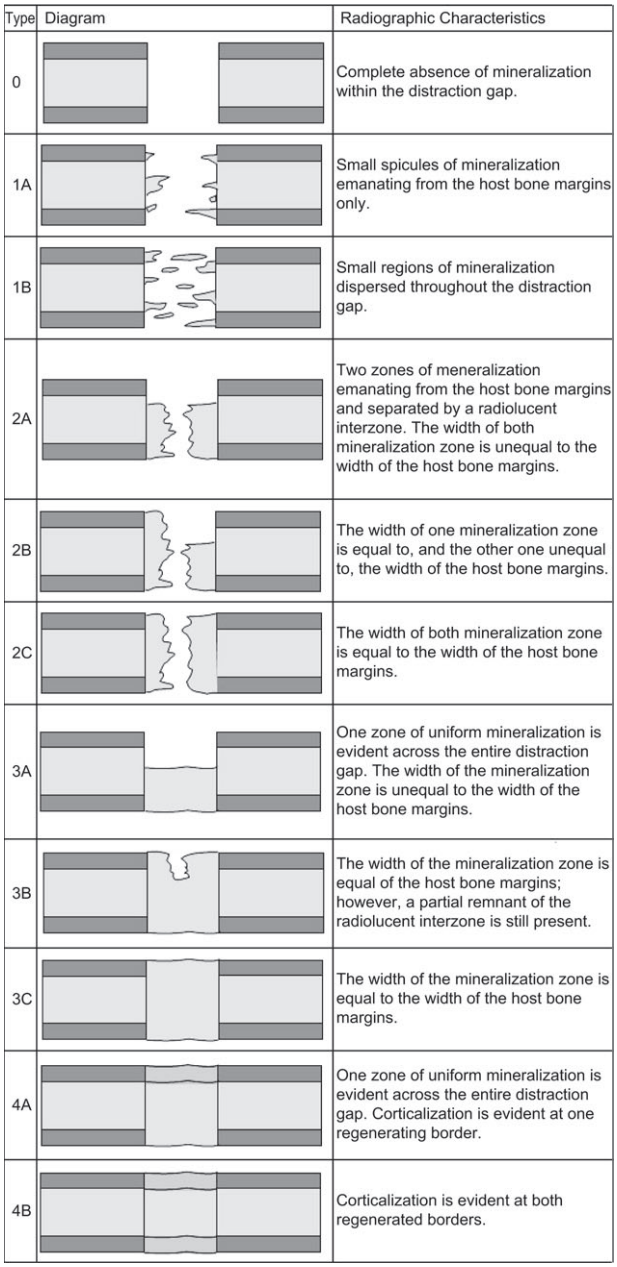

Figure 6 Radiographic classification of regeneration after mandibular distraction (Samchukov *et al.*, 2001).

Interdental width change during the post-distraction follow-up period (T2–T3). The widths of the CEJ at the canine (1.0 ± 1.22 mm), the cusp tip, and the CEJ at the first premolar (1.4 ± 2.24 and 1.3 ± 1.18 mm, respectively) were significantly decreased.

Interdental width change during the total observation period (T1–T3). The total amount of expansion (the amount of expansion excluding relapse) was calculated. The anterior area of the arch was more expanded than the posterior, and the cusp tip was more expanded than the CEJ vertically (Table 3).

Arch length and irregularity index during the total observation period (T1–T3). Arch length was significantly increased to 3.7 ± 3.41 mm ($P < 0.001$) and irregularity significantly decreased by 7.1 ± 4.86 mm ($P < 0.001$: Table 4).

Radiographic healing patterns (n = 11 patients)

Consolidation week 0. After distraction, there was no evidence of mineralization in seven patients. The only mineralization observed was in the gap in four subjects (Table 5).

Consolidation 1–2 weeks. There was no evidence of mineralization in three patients. In one, the width of the mineralization zone was equal to the width of the host bone [Figure 6(2C)]. The remaining seven patients showed small spicules at the host bone margins [Figure 6(1A), three patients], small irregularly arranged islands of mineralization were throughout the gap [Figure 6(1B), two patients], the width of both mineralization zones was not equal to the width of the host bone margins [Figure 6(2A), one patient], or the width of one mineralization zone was equal to, and the other unequal to, the width of the host bone margins [Figure 6(2B), one patient].

Consolidation 3–4 weeks. There was further progression of mineralization in all patients. In one, there was one zone of uniform mineralization across the entire distraction gap [Figure 6(3A)].

Consolidation 11–12 weeks. Further progression of mineralizaiton was observed in all patients, with evident corticalization in one regenerated border of one patient.

Discussion

DO procedures have been proposed as an alternative therapy for patients requiring major craniofacial reconstruction, including mandibular lengthening in hemifacial microsomia and micrognathic subjects. The use of MSDO which was called ‘surgical rapid mandibular expansion’ was pioneered by Guerrero (1990) and Guerrero and Contasti (1992).

The advantages of the surgical technique in DO include versatility, minimal invasiveness, stability, a short procedure, and no donor site morbidity. Because patients are treated in an ambulatory surgical setting under local anaesthesia and intravenous sedation without hospitalization, the cost of treatment is significantly reduced. Control of the mandible and its enveloping soft tissue, without bone graft are additional clinical advantages and early treatment with the use of an osteodistraction appliance may prevent both functional and psychosocial problems in many adolescents (Guerrero *et al.*, 1997).

The disadvantages of DO include patient compliance and the need for almost daily monitoring of the distraction gap and appliance.

In this study, the amount of expansion by DO was significantly increased at the interdental widths (Table 1).

Table 1 The amount of pure expansion (T2–T1) by distraction osteogenesis (n = 19 patients).

Interdental space	Pre-distraction (T1)		Post-distraction (T2)		Change (T2–T1)	
	Mean	SD	Mean	SD	Mean	SD
3–3 cusp tip	23.6	2.19	28.1	1.95	4.5***	1.64
3–3 CEJ	29.2	2.96	33.0	1.88	3.8***	1.69
4–4 cusp tip	33.0	2.81	37.1	2.24	4.1***	2.30
4–4 CEJ	39.5	2.82	42.6	2.35	3.1***	2.15
6–6 mesiobuccal cusp	45.4	2.88	48.5	2.77	3.0***	2.04

CEJ, cementoenamel junction; SD, standard deviation; ***$P < 0.001$.

Table 2 The difference between follow-up (T3) and post-distraction (T2), n = 19 patients.

Interdental space	Post-distraction (T2)		Follow-up (T3)		Change (T3–T2)	
	Mean	SD	Mean	SD	Mean	SD
3–3 cusp tip	28.1	1.95	27.7	1.58	−0.4	2.17
3–3 CEJ	33.0	1.88	32.0	2.05	−1.0**	1.22
4–4 cusp tip	37.1	2.24	35.8	2.09	−1.4*	2.24
4–4 CEJ	42.6	2.35	41.4	2.32	−1.3***	1.18
6–6 mesiobuccal cusp	48.5	2.77	47.9	3.09	−0.5	1.88

CEJ, cementoenamal junction; SD, standard deviation; *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$.

Table 3 The amount of total expansion (the amount of expansion excluding relapse) by distraction osteogenesis (n = 19 patients).

Interdental space	Pre-distraction (T1)		Follow-up (T3)		Change (T3–T1)	
	Mean	SD	Mean	SD	Mean	SD
3–3 cusp tip	23.6	2.19	27.7	1.58	4.2***	2.07
3–3 CEJ	29.2	2.96	32.0	2.05	2.8***	1.53
4–4 cusp tip	33.0	2.81	35.8	2.09	2.7**	3.03
4–4 CEJ	39.5	2.82	41.4	2.32	1.9**	2.19
6–6 mesiobuccal cusp	45.4	2.88	47.9	3.09	2.5***	2.30

CEJ, cementoenamal junction; SD, standard deviation; **$P < 0.01$, ***$P < 0.001$.

Theoretically, MSDO should produce greater width increases in the anterior than in the posterior part of the mandible and in the upper part (cusp) of the teeth than in the lower part (CEJ). Intercanine width increased more than intermolar width and intercusp width more than inter-CEJ width. To determine the amount of calcification after post-distraction, the data of T2 was compared with T3. All widths, except the inter-cusp width of the canine and first molar were significantly changed.

The question then arises as to whether or not the change was due to pure relapse of DO. All patients, except one, were undergoing or had undergone orthodontic treatment. This means that there were tooth movements after post-distraction. The space resulting from symphysis DO is used for relief of crowding and for alignment of a collapsed arch. Therefore, the study of pure stability after DO is not simple and the timing of measurements is an important factor.

Arch length was increased and irregularity decreased from T1 to T3.

In a classic study of stability and relapse of mandibular anterior alignment in first premolar extraction cases treated by traditional edgewise orthodontics, Little *et al.* (1981) followed 65 subjects for at least 10 years post-retention. The results of their study indicated that there were no predictors of instability. Alignment was variable and unpredictable, arch width and length decreased, crowding increased, and the rate of success was approximately one-third. A similar long-term evaluation, by Little *et al.* (1988), of changes in mandibular alignment from 10 to 20 years post-retention, demonstrated that there was a continued decrease in mandibular arch length

Table 4 The change in arch length and irregularity following mandibular distraction osteogenesis (n = 19 patients).

Variables	Pre-distraction (T1)		Follow-up (T3)		Change (T3–T1)	
	Mean	SD	Mean	SD	Mean	SD
Arch length	57.1	3.87	60.8	4.39	−3.7***	3.41
Irregularity	9.5	4.88	2.4	1.93	7.1***	4.86

SD, standard deviation; ***$P < 0.001$.

Table 5 Radiographic characteristics of mandibular distraction regenerates (n = 11 patients).

No.	Consolidation period			
	0 week	1–2 week	3–4 week	11–12 week
1	0	1B	2C	3B
2	1A	2B	2B	2B
3	1A	1A	2C	4A
4	0	1A	1B	2A
5	2A	2A	3A	3C
6	0	1B	2A	3C
7	0	0	1B	2C
8	2A	2C	2C	3C
9	0	0	1A	1A
10	0	0	1A	2C
11	0	1A	1B	2A

and arch correction that did not cease after active growth. They recommended that long-term retention was needed and most premolar extraction cases were not stable.

Proclination of the mandibular incisors during distraction is of clinical concern. Del Santo *et al.* (2000, 2002) observed significant proclination in patients who did not have orthodontic wires placed before distraction. They considered that proclination of the lower anterior teeth was probably due to the distraction pattern of the tooth-borne device, which disproportionately rotated the segments laterally and anteriorly. Such proclination of the lower anterior teeth, although minimal, may increase the risk of relapse. However, patients who had orthodontic wires in place when the post-distraction radiographs were taken showed no changes in incisor inclination, indicating that orthodontic treatment compensated for the proclination of lower anterior teeth produced by distraction.

Using the classification system suggested by Samchukov *et al.* (2001), the stage of bone formation in the distraction gap was classified. In their study, they used 13 skeletally mature male beagle dogs and performed bilateral midbody osteotomies. They classified 11 types of mandibular distraction regeneration. In the present study, the stage of bone formation on the distraction gap in 11 patients was classified. Individual variations with mineralization were evident in all patients within 3 weeks after the end of activation.

This was a retrospective study with a limited sample size that did not include complete records for all subjects. Future prospective longitudinal studies with a sufficient numbers of subjects are necessary to evaluate distraction and post-distraction changes. Skeletal stability is more important than dental stability; however, the amount of distraction and relapse in the anterior skeletal region could not be measured due to the lack of stable reference structures. The use of metallic bone markers is recommended. Expansion by symphysis DO with a tooth-borne device can result in more dental expansion as compared with the basal bone (Del Santo and Guerrero, 2000). That means minor dental relapse exists. In this study, tooth-borne, bone-borne, and hybrid (tooth and bone-borne) devices were used. Future studies are necessary to distinguish the differences in relapse patterns according to the different devices.

Finally, the majority of the patients were still undergoing orthodontic treatment when the impressions were taken. It is necessary that subjects are at the debonding stage when taking impression for accurate post-retention results.

Conclusions

MSDO has many advantages compared with conventional orthodontic treatment, and is an efficient and stable treatment method in skeletal transverse deficiency of the mandibular arch. The results of this study show that:

1. Although there was a relapse during orthodontic treatment, the total amount of expansion was maintained.
2. Arch length was significantly increased and irregularity was significantly decreased.
3. There was evidence of mineralization of the distraction gap within 3 weeks after the end of activation in 11 patients.
4. Radiographically, the healing patterns of the distracted gaps were diverse, but radiopacity increased with time.

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