Changes in the temporomandibular joint after mandibular lengthening with different rates of distraction

This study assessed the changes in the condyle after mandibular lengthening with 2 different rates of distraction (1 mm/day and 2 mm/day). Unilateral mandibular distraction was performed in 8 young adult goats. The animals were sacrificed 8 weeks after the completion of distraction, and the temporomandibular joint (TMJ) specimens were harvested and processed for histologic examination and histomorphometric analysis. Adaptive changes in the condyle were observed in the goats distracted at a rate of 1 mm/day, whereas degenerative alterations were found in those distracted at a rate of 2 mm/day. This study suggests that the TMJ is able to withstand the impact of distraction at a rate of 1 mm/day, but more rapid distraction may induce degeneration in the condylar cartilage. (Int J Adult Orthod Orthognath Surg 2001;16:221–225)

In recent years, mandibular distraction osteogenesis has become more prevalent as a safe and effective technique for lengthening the hypoplastic mandible because of its advantages over conventional orthognathic surgery and bone grafting procedures. However, concern still exists that the compressive forces resulting from distraction may lead to posterior displacement of the condyle and development of temporomandibular disorders.

Although a number of studies have reported the effect of mandibular distraction on the temporomandibular joint (TMJ),1–3 the changes in the TMJ, especially their correlation with the rate of distraction, have not yet been elucidated. The purpose of this study was to evaluate the changes in the TMJ after mandibular lengthening by distraction osteogenesis using 2 different rates of distraction in a goat model.

Materials and methods

Eight young adult male goats weighing 20 to 25 kg were randomly divided into 2 groups, which were designated group A (n = 4) and group B (n = 4). Under anesthesia with intravenous injection of 35 mg/kg pentobarbital and local administration of 1% lidocaine, a corticotomy was performed anterior to the first molar in the right mandibular body. A custom-made distractor was placed with screws through a submandibular incision. After a latency period of 7 days, the distractor was activated at a rate of 1 mm/day (0.5 mm every 12 hours) for 10 days in group A and 2 mm/day (1 mm every 12 hours) for 5 days in group B, producing 10 mm of elongation in the operated mandible.

All animals were sacrificed 8 weeks after the completion of distraction. Both sides
of the TMJ were harvested en bloc. The specimens were fixed in 10% neutral buffered formalin, then decalcified with 0.5 mol/L EDTA. Each condyle was divided sagittally into 3 blocks (lateral, middle, and medial thirds) and processed for histologic examination with hematoxylin and eosin staining. Each block was further divided into 5 sagittal sections. Two additional nonoperated goats of the same age and weight were used as controls, and their condyles were prepared in the same manner. In each condyle, 1 of the 5 sagittal sections per block (lateral, middle, and medial) was chosen at random and examined on the anterior, superior, and posterior aspects. In addition to general histologic observation, a histomorphometric analysis was performed on these sections to measure the thickness in the fibrous and cartilage layers via a computer system using the OPTIMAS 6.0 Image 2 software (Media Cybernetics). The mean thicknesses were obtained from group A, group B, and control animals.

For statistical analysis, the Student t test, the chi-square test, and analysis of variance were used to assess within-group and between-group differences. Probabilities of .05 or less were considered significant.

Results

At the end of distraction and during the period of consolidation, all group A and B animals showed an obvious asymmetric protrusion of the mandible (Fig 1). At sacrifice, newly formed calluses were clearly visible in the elongated mandible and confirmed by radiographic examination (Fig 2). The TMJ specimens had intact condylar and fossa morphology, with slight flattening of the posterior condyle. There were no gross differences in the shape and appearance of the TMJs between group A and group B.

Histologic changes in the TMJs after unilateral mandibular lengthening by distraction osteogenesis are shown in Figs 3a to 3c. Data regarding the mean thickness of fibrous and cartilage layers are shown in Table 1. In group A, the fibrous layer of the condyle was thicker than that in the control specimens ($P < .05$). Although the fibrous layer lost density, the collagen fiber bundles maintained their regularity. The cartilage layer showed a significant increase in thickness over that in the control specimens ($P < .05$). Furthermore, hypertrophic chondrocytes and active osteoblasts in the area of the cartilage/bone interface were remarkable. New bone deposition in the region
underneath the cartilage layer was also observed (Fig 3a). The posterosuperior aspect of the condyle appeared to be more involved within these adaptive changes. In group B specimens, the fibrous and cartilage layers were thinner than in group A specimens ($P < .05$) and control specimens ($P < .05$). Disorganization of collagen fibrils was frequently seen. In some sections, the cartilage layer showed degeneration and necrosis of chondrocytes, and it even disappeared in some areas (Figs 3b and 3c). These signs of degenerative changes in the TMJ also seemed to concentrate on the posterosuperior surface of the condyle. On the other hand, no significant difference was found in the histology and changes in the thickness of fibrous and cartilaginous layers between the distracted side and contralateral side in either group A or group B.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Group A</th>
<th>Group B</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distracted side (n = 4)</td>
<td>Contralateral side (n = 4)</td>
<td>Mean</td>
</tr>
<tr>
<td>Fibrous layer</td>
<td>338 ± 125</td>
<td>354 ± 114</td>
<td>346 ± 119</td>
</tr>
<tr>
<td>Cartilage layer</td>
<td>297 ± 107</td>
<td>318 ± 113</td>
<td>308 ± 111</td>
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</table>

Table 1 Thickness of fibrous and cartilaginous layers (mean ± SD, in µm) in condyles taken from group A, group B, and control specimens.


Discussion

During mandibular distraction, although the body of the mandible receives a direct stretch, the distant condyle against the articular fossa undergoes indirect compression. During lengthening of the mandible, the proximal segment with the condyle may be moved backward and exert stress on the condyle surface. Compressive loading may induce alterations in the disc, condyle, and disc-condyle relationship, and posterior displacement of the condyle could result in degenerative changes in the articular cartilage. Consequently, there has been a great concern that mandibular osteodistraction may create TMJ problems.

With a distraction rate of 0.5 to 1.0 mm/day, McCormick et al. and Karaharju-Suvanto et al. found that mandibular distraction can induce TMJ remodeling, with adaptive changes in the cartilage and bone structure, but that these effects are mild and reversible. Conversely, Harper et al. reported reactive changes in the fibrous layer, cartilaginous layer, and bone/cartilage interface after mandibular midline osteodistraction. The severity of these changes, including bone resorption, was correlated with the likely rotational forces directed at the condyle. Karaharju-Suvanto et al. demonstrated similar histologic changes in the condyles with distraction amounts ranging from 3.5 mm to 8.5 mm. Despite the fact that McCormick et al. found that flattening of the posterior condyle and thinning of the cartilage in dog mandibles elongated by 20 mm were more pronounced than that in mandibles lengthened by 10 mm, no evidence of degenerative alterations was noted. These findings imply that there is no significant relationship between the amount of distraction and morphologic changes of the condyle. Recently, there have been some animal studies regarding the effect of distraction rate on bone regeneration within the distraction gap. However, little is known about the impact of the distraction rate on the TMJ following mandibular osteodistraction.

In this study, we have compared the differences in histologic changes of the condyle, based on 2 different rates and the same length gain, after mandibular distraction in goats. The results demonstrated that a distraction rate of 1 mm/day induced adaptive changes in the TMJ, and that a rate of 2 mm/day caused moderate degeneration in the articular cartilage. The rate of distraction therefore appears to play an important role in the response of the TMJ to mandibular distraction. Additionally, the present study showed that unilateral gradual lengthening of the mandible can affect both the distracted and contralateral sides of the TMJ. This finding is consistent with earlier reports. Karaharju-Suvanto et al. observed slight differences in the histologic changes between the operated side and nonoperated side. However, our data did not show any significant difference in the alterations of the condyle between the 2 sides. The reason might be that we lengthened the body of the mandible, whereas Karaharju-Suvanto et al. distracted the mandibular ramus.

Articular cartilage in the condyle that is covered with fibrous connective tissue has more adaptive potential, because it helps the TMJ to withstand environmental stress to a better extent than other long bone fibrous joints. However, if compressive forces resulting from distraction exerted on the condyle are beyond the adaptive capacity of the TMJ, degeneration or damage to the cartilage will occur. Previous studies have found that rapid distraction could result in the delay or failure of osteogenesis. The present study showed that a rate of 1 mm/day was tolerable and safe to the TMJ, but a higher rate of distraction led to degenerative changes in the condyle. It may be concluded that rapid distraction not only has adverse effects on bone regeneration but also on the TMJ.

Acknowledgment

This study was supported by the Natural Science Foundation of China, project proposal #39970797.
References


