An Analysis of Knee Joint Sound in Patients with OA, PF Disorders and Meniscal Lesions

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Abstract: Using a double microphone and a 2-channel frequency analyzer we analyzed the frequency of the joint sound emitted during flexion and extension of 67 patients with end-stage osteoarthritis (OA) of the knee, 60 patients with patellofemoral joint (PF) disorders and 10 patients with lateral meniscal bucket handle tears. By performing a frequency analysis of the joint sound emitted before and after the intra-articular injection of Hyaluronic acid (HA) in 47 patients of end-stage OA and 50 PF disorder patients, we evaluated the efficacy of HA in improving joint lubrication, which is an important physiological function of HA. We found that the joint sound frequency of OA knees and PF disorders tended to differ from those cases with lateral meniscal bucket handle tears. The joint sound frequency spectrum of end-stage OA knees and PF disorder patients after intra-articular HA administration was significantly lower than that before administration. These results indicate that the intra-articular administration of HA to the knee can effectively improve the lubricative function.

Key words: joint sound, osteoarthritis, Hyaluronic acid, diagnosis

Introduction

The sounds used in making audible sounds, such as those of the respiratory and circulatory systems, and in addition to audible sounds various other sounds exist such as those heard using the ultrasonic scanner. In the same way, if the sounds emitted from the joints are utilized in making a diagnosis, this painless and fast examination method is thus considered to be valuable for both orthopaedic surgeons and patients. There have been numerous reports describing joint sound, but few such reports exist in the field of orthopaedic surgery because no criteria for such analyses have yet been established.

Osteoarthritis of the knee joint (OA), patellofemoral joint disorders (PF) and meniscal lesions are all representative of diseases emitting sounds from the knee joint. Using a double microphone, we thus measured knee joint sounds and then performed a computer analysis of the fast Fourier transform joint sound frequency in an attempt to analyze the knee joint sounds in patients with confirmed OA, PF disorders and meniscal lesions.

The intra-articular administration of HA is
a widely practiced method for the treatment for OA of the knee, and numerous reports have been published concerning its clinical efficacy and treatment results.\textsuperscript{1,2,6,12} However there have so far been no reports indicating the efficacy of measuring knee joint sound. HA is a macromolecular and highly viscous substance. It is thought that HA improves the lubricative function of the knee joint by covering the worn articular surface. Using joint sound, we thus evaluated and investigated the HA efficacy in cases of both OA of the knee and PF disorders.

**Materials and Methods**

**Joint sound measurement by disorder**

We investigated 67 knees of 67 end–stage OA patients who showed a loss of joint space on radiographs and exposure of the subchondral bone of the femorotibial joint (mean age, 67.9 years, range, 54 to 85 years), 60 knees of 60 PF disorder patients with no OA changes to the femorotibial joint as seen on radiographs and positive patella–compression test results (mean age, 41.1 years, range from 27 to 62 years), and 10 knees of 10 cases of lateral meniscal bucket handle tears (mean age 37.6 years, range from 17 to 45 years). All end–stage OA knee patients underwent a total knee replacement or high tibial osteotomy, and the meniscal lesion patients underwent a meniscectomy under arthroscopy. The preoperative joint sounds of these cases, which were confirmed during knee flexion and extension, were also measured.

**HA efficacy on joint lubrication improvement**

We investigated 47 knees of 47 end–stage OA knee patients which emitted joint sound, with an average age of 68.9 years (range, 54 to 81 years), and 50 knees of 50 PF disorder patients which showed no OA changes in the femorotibial (FT) joint on radiographs but which also emitted joint sound, with an average age of 40.3 years (range from 27 to 58 years). These patients were administered a single dose consisting of 2.5 ml of HA. The joint sound was measured both before and after the intra-articular injection of HA. Furthermore, the joint sounds in 50 PF disorder patients were measured at 24 hours, 48 hours and one week after HA administration. Thirty–six of the 47 end–stage OA knees and 40 of the 50 PF disorder patients were also injected with a steroid solution containing 2 ml of Lidocaine on a day different from that when HA was administered. The joint sounds of these 76 knees were measured both before and after the intra–articular injection of the steroid solution and were used as a control group, henceforth referred to as the steroid administration group.

The joint sounds were recorded in an anechoic chamber using B & K model 4189 microphones fed into a model 2148 2–frequency channel analysis device, after which the fast Fourier transform frequency spectrum was analyzed. The assembly was set up so that the output of the two microphones passed through a differential amplifier where the said component was cancelled out. The tops of the two microphones were staggered with a distance of 10 mm between them. The microphones were attached to a tripod, and then the joint sounds emitted when the patient did half squats on one leg with a knee flexion angle ranging from 30–60° were measured. For the cases with meniscal lesions, the patient was seated and the joint sound emitted when the knee was extended from a 45° flexion angle to full extension was recorded. Figure 1 shows the frequency spectrums of each disease. The maximum spectrum power is shown in red, and as indicated by the diagram, it is singularly recognizable within an extremely limited frequency domain (Fig. 1). For the frequency value of the measured joint sound, we used the maximum spectrum power, namely, the value of the area shown in red. Statistical analyses were performed using the unpaired T–test.

**Results**

i) **Knee joint sound results by disorder**

The mean frequencies of the patients with confirmed end–stage OA knees and PF disorders were 433 Hz (S.D. 121.0) and 544 Hz (S.
D. 167.6), respectively. The mean frequency of the lateral meniscal bucket handle tear patients was 174 Hz (S.D. 47.2), thus indicating a tendency to be slightly lower than patients with articular cartilage damage, such as end–stage OA knees and PF disorders (Fig. 2).

ii) The efficacy of HA on joint sound in OA and PF patients
The mean frequency of the end–stage OA knees prior to HA administration was 427 Hz (S.D. 141.1), while the mean frequency immediately after administration was 283 Hz (S.D. 86.5), thus indicating a significant lowering in frequency (p<0.0001) (Fig. 3). For the PF disorder patients, the HA pre–administrative mean frequency was 524 Hz (S.D. 110.4) and the mean frequency immediately after administration was 355 Hz (S.D. 87.5), thus indicating a significant lowering in frequency (p<0.0001).

iii) HA post–administrative joint sound changes over time in PF patients
In addition, when the changes over time after HA administration in the PF disorder patients were examined, the frequencies at 24 hours after administration were also significantly lower than the pre–administrative values (P<0.001). However, no significant differences in frequency were observed among the pre–administration values, at 48 hours after administration and at 1 week after administration (Fig. 4). In the steroid administration group, the pre–administrative mean frequency was 416 Hz (S.D. 8.7) while the mean frequency immediately after administration was 410 Hz (S.D. 7.0), thus indicating no significant difference. We also

![Fig. 1](image1.png)  
**Fig. 1** A diagrammatic representation of each disease.

![Fig. 2](image2.png)  
**Fig. 2** The mean frequencies of the various diseases. The joint sound mean frequency of cases with confirmed meniscal lesions tended to be lower than those of end–stage OA and PF disorders.
found no significant difference in the pre-administrative and post-administrative mean frequencies of the PF disorder patients, which were 546 Hz (S.D. 37.4) and 537 Hz (S.D. 5.0), respectively (Fig. 5).

**Discussion**

Since the first clinical application of diagnostic joint sound reported by Hueter, numerous studies have been reported. However, there have been few reports describing the frequency spectrum changes for various diseases. As in the past, we used a
double microphone to measure the joint sounds. Recording the joint sounds was carried out in an anechoic chamber, and we endeavored to reduce the ambient sound. To make a more detailed analysis of the peak values of the various frequency levels, we added a time axis by computer and analyzed the spectrums. As a result, we were able to graph the frequency, time and sound pressure spectrums using color, which thus enabled us to obtain a more accurate understanding of the joint sound characteristics.

The articular cartilage damage which occurs in OA knees and PF disorders is caused by an increase in friction and impact between the articular cartilage and the bones, which thus results in the emission of joint sound. Sasaki et al., in 1995, investigated the changes in joint sound during movement after inflicting mechanical injuries on the articular cartilage of pig knees. In the case of meniscal lesions, the arthroscopic findings during surgery showed all the patients to have bucket handle tears. The emission of sound is thought to be the result of an increase in friction between the cartilage of the femur and the tibia during knee extension when the torn meniscus is repaired. In addition, Inoue and Sasaki et al. stated that changes in joint sound frequency and sound pressure occurred due to the load and the amount of friction. Our analysis results also indicated that the joint sound frequencies in patients with OA knees and PF disorders with articular cartilage damage differed from those in cases with lateral meniscal bucket handle tears.

There have been numerous reports concerning the HA treatment by intra-articular injection for cartilage injury. However, there are no reports describing the efficacy of HA for improving lubricative functions, which is an important physiological function of HA, by analyzing the frequency of the knee joint sound.

All individuals experience some small degree of low sound of low friction movement on a daily basis. Therefore, if the use of HA for OA knees, which are thought to have high friction joint movement following articular cartilage damage, results in an improved lubrication, then we can expect to see changes in the joint sounds emitted due to friction. In this study, our results indicated the joint sound frequency after the administration of HA to be significantly lower than the pre-administrative frequency. This suggests that the intra-articular administration of HA indeed improves articular lubrication. We consider a frequency analysis of knee joint sound to be helpful in diagnosing these three above-mentioned dis-
eases and also for evaluating the articular lubricative function.

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References


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