ACOUSTIC EMISSION TECHNIQUE IN LOCATING KNEE OSTEOARTHRITIS

Md. T. I. Khan, M. M. Hassan, Y. Hasemura, N. Matsuo
Department of Advanced Technology Fusion, Saga University, Saga 840-8502, Japan
email: khan@me.saga-u.ac.jp

S. Ide
Department of Orthopaedic Surgery, Saga University, Saga 849-8501, Japan
e-mail: ideshuy@cc.saga-u.ac.jp

Acoustic emission (AE) technique has been investigation for identification and location of osteoarthritis in knee joint. Although, AE technique has widely been used for years as a NDT tool in damage monitoring and condition inspection of industrial and structural materials, similar applications of AE technique has been considered in integrity analysis of knee joint as well. Of course, integrity analysis of knee joint involves a detail study of several anatomical parts of knee joint like bones, cartilage, tendons etc. However, the interest of the present investigation has been confined to knee osteoarthritis which is considered to be caused due to the degeneration of knee cartilage. The incidence of this widely manifested knee disease increases in aging society. The major concern of this disease is its incurability at its matured stage. However, early detection for adopting appropriate measures can reduce the risk of this disease. The present investigation focuses on the dynamical behavioral characterization of knee joint for its integrity analysis with acoustic emission characterizing parametric features of AE signals. Data has been collected from the participants with different age groups without any knee problems as well as with knee problems (OA). All data have been clarified for identifying the technique as a clinical tool in monitoring knee condition effectively.

Keywords: AE technique, knee osteoarthritic location.

1. Introduction

Early identification of cartilage damage in knee joint is an important factor in reducing the impact of knee problem or osteoarthritic disease in aging society. However, unavailability of suitable diagnostic measure makes impossible for early knee damage identification of knee joint. Anatomically, three bones and various ligaments consist the knee joint. Accordingly, these three bones, femur (the thigh bone), tibia (the shin bone), and patella (the kneecap) are known as three major components of this joint [1]. Knee joint provides necessary support to the skeleton for allowing them to be flexible in movements. This motion control as well as the protection of the knee joint is done by several muscles and ligaments. These ligaments of the knee ensure that the body-weight must be transmitted through the knee axis for minimizing the amount of wear and tear on the cartilage inside the knee [2].

Bones in knee joint are receiving cushiony supports by cartilage, synovial membrane and fluid inside the joint. Moreover, muscles and ligaments provide the appropriate forces and strength to this joint for
its stable movements. However, due to getting ages, the quality of bones including the cushiony items are degenerated. Furthermore, the quality as well as the quantity of muscle and synovial tissues are also degraded due to aging and thus, the balance movements of knee joint are decreased. Therefore, the surface roughness of the articular cartilage is increased and the risk of happening the osteoarthritis (OA) is also increased [3].

Dynamic analysis of knee joint consists of the analysis of knee’s integrity in anatomical parts during movements of sitting and standing. Major objectives of this study are to develop a simple bio-marker for clarifying the abnormalities of knee joint like OA in its early stage or matured stage due to aging or any other causes. Furthermore, for better understanding about the intensity as well as the location of this disease in initiation and propagation are also important factors for clinical treatment of OA. [4].

Present potential methods like X-ray, magnetic resonance imaging (MRI) etc. are using for clinical diagnosis of knee diseases. However, inserted high external energy to the body for diagnosis in these techniques and the high cost as well as several obscureness and static sensitivity make them unpleasant and complicated to the patient. In the contrary, proposed acoustic emission (AE) technique is considered safe and user-friendly in diagnosis of knee joint with low cost and safe in its dynamic diagnosis mode.

In the present research, integrity analysis of knee joint by AE technique has been evaluated perspective to its application in damage location as well as datum-line detection for its wider and clinical applications.

2. Experimental methodology

According to the objectives of the present research, four AE sensors were attached to the knee joint. For avoiding noise from muscle, tendon etc. sensors were placed near to the knee bones, two of them to the femur and two to the tibia according to the experimental observations [8]. All AE sensors (R6α, Physical Acoustics Corporation) were attached to the knee with high elastic medical tape for avoiding undesirable noise during sit-stand-sit movements. Furthermore, coupling gel was used between the surface of the sensor and the contact place of the knee for keeping continuous contact of the sensing surface to the anatomical site of the knee. For getting an angular position of knee movements, electronic goniometer (SG150, Biometrics Ltd.) was attached to the knee joint. One movement of sit-stand-sit consisted one cycle. Three cycles of movements consisted of one set. One-minute rest was taken as intermittent rest time for going to next set. Repeating the same system, five sets of data had been collected. AE Win Software (Physical Acoustics Corporation) was used for collecting AE data from knee joints.

![Figure 1 Schematics of experimental methodology](image-url)
In experiments, for avoiding noise, height adjustable chair was used for all participants in siting activities. Furthermore, hands were kept constant neat the chest for avoiding movement noise. According to the schematics (Fig. 1), acquisition of AE data was performed. After amplification data were saved to a personal computer (PC in Fig. 1). Similarly, angular data were taken by goniometer and transferred to the PC for further analysis.

Furthermore, in continuous AE data acquisition of the experiment, received several unwanted data (crypts noise, etc.) was removed by applying special filtering system as well. Afterwards, AE parameters analysis were done by specially coded MATLAB software.

3. Experimental results and discussion

Four groups of participants, young participants (A group: 24.2yrs. average), middle aged participants (B group: 48.6yrs. average), old aged participants (C group: 65.4yrs. old average) and OA patients were joined to the experiments. Healthy people (groups A, B and C) were defined healthy based on the participant’s opinion as none of them were suffered from knee problems. The participants of D group were patients who suffered from knee osteoarthritis. All participants joined the experiment based on basic ethical declarations and procedures of the Saga University. Furthermore, special care for the participants in the experiment was taken according to their pain and cartilage damage conditions. The objective of joining participants without pain was to identify the evaluation procedure of initial condition of cartilage damage, on the other hand, the objective of joining knee patients to the experiments was to identify the evaluation procedure of damaged knee. Several biomarkers were selected to clarify the damage conditions of knee joint, out of which two influential biomarkers as AE maximum amplitude distribution and angular positions of AE hits are explained below.

3.1 Amplitude distribution criteria

As an influential biomarker the average amplitude distributions of AE events are shown in Fig. 2. It was considered that the increase of damage in cartilage surface increases the AE amplitude. Thus, it is seen in Fig 2 that increasing participant’s age increased AE event amplitudes, and group D showed it maximum as the cartilage damage in this group was maximum. Filtering was done for avoiding noise.

Figure 2: Amplitude distribution of AE hits for all groups of participants.
3.2 Positioning of cartilage damage

Maximum amplitudes of each AE events for total sets of data were summarised at the related angular position of knee of a participant and thus total events amplitudes are thus presented in Fig. 3. Evaluated thresholds for each group of participant groups are also shown in the figure. Therefore, the total damage conditions of the cartilage surface can be evaluated from shown figure as well. For example, it is found in the figure that at 15 to 20 degrees and 60 to 95 degrees, the damages were degraded over the red line as well. On the other hand, good condition of cartilage surface is also shown at 0 to 10 degrees, 40 to 45 degrees or above 115 degrees.

![Figure 3: Angular distribution of AE signal amplitude for OA patient in damage detection.](image)

4. Conclusions

Locating the damage conditions and positions of knee joint due to OA was clarified based on AE technique. Appropriate filtering had been applied successfully in avoiding crypts noise etc. during continuous acquisition as well in the present system.

5. Acknowledgement

The research is supported by the Grants-in-Aid for Scientific Research (KAKENHI 17K06266) from the MEXT of the Government of Japan. Authors are grateful to all other supporters, volunteer participants and staffs to this research as well.

REFERENCES


