INVESTIGATION OF KNEE JOINT INTEGRITY DUE TO AGING EFFECT ON OSTEOARTHRITIS BY ACOUSTIC EMISSION TECHNIQUE

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Investigation of integrity condition of knee joint by applying Acoustic emission (AE) technique has been investigated. Although, AE technique has widely been used for years as a NDE tool in damage inspection and condition monitoring of industrial and structural materials as well as in their applications, similar applications of AE technique are expanding recently in different fields as well. Integrity analysis of knee joint involves a detail study of several anatomical parts of knee joint like bones, cartilage, tendons etc. Any damage of these anatomical parts causes several knee diseases like osteoarthritis (OA). The incidence of knee OA, a widely manifested knee disease, particularly in aging society, increases due to some damages in cartilage of knee joint. The major concern of this disease (OA) 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 (AE) characterizing parametric features. AE signals have been collected from different positions of tibia, patella, femur etc. sensors with adaptive frequency bands for getting sufficient information about the condition of cartilage in knee joint. Data has been collected from the participants with different age groups without any knee problems as well as participants with knee diseases. All data have been clarified effectively to identify the proposed technique as a clinical application tool of monitoring knee condition in early stage for removing the risk of OA effectively.

Keywords: acoustic emission, biomarker, integrity analysis of knee joint, osteoarthritis.

1. Introduction

Anatomically constructed of three bones and various ligaments consists the knee joint up of three bones and various ligaments. Femur (the thigh bone), tibia (the shin bone), and patella (the kneecap)
are the major components of this joint [1]. Knee joint provides necessary supports to the skeleton for allowing them to be flexible in movements. The motion control as well as the protection of the knee joint is done by several muscles and ligaments [2]. 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 [3].

Bones in knee joint are receiving cushiony supports by cartilage, synovial membrane and fluid inside the joint [4]. 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 [5, 6].

The dynamic analysis of knee joint consists of the integrity analysis of knee’s anatomical parts for several movements of sitting and standing. Major objectives of this study are to develop a simple bio-marker for clarifying the initiation of knee disorder responsible for OA due to aging, and also to diagnosis the matured OA in knee joint. The disease of OA increases with age due to some damages in cartilage of knee joint [7].

Potential methods like X-ray, magnetic resonance imaging (MRI) etc. are presently using for clinical diagnosis of knee diseases. However, externally inserted high energy to the body for diagnosis of these technique and their static sensitivity with high cost make them unpleasant to the patient. In the contrary, proposed acoustic emission (AE) technique is considered safe and user-friendly diagnosis of knee joint with low cost in dynamic analysis mode.

In the present research, integrity analysis of knee joint was planned to be conducted by applying AE technique to young aged, middle aged and old aged volunteers with no knee pain or knee problems (self-declared) as well as knee patients in dynamic movements (sit-stand-sit) of their knees.

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 to nearest to the knee bones as two to femur and tow to tibia according to the experimental observations [8]. Four AE sensors (R6xa, Physical Acoustics Corporation) were attached to the four positions of knee joint 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 the knee during the movement, electronic goniometer (SG150, Biometrics Ltd.) was attached to the knee joint. In one cycle of movement (sit-stand-sit) the goniometer angle was recorded as 180 degrees. Three cycle of movements consisted of one set, while 1 minute was taken as intermittent rest time for going to next cycle. 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.

In experiments, for avoiding noise, height adjustable chair was used for all participants in sitting activities. Furthermore, hands were kept constant neat the chest for avoiding movement noise. According to the schematics (Fig. 1), acquitting data were amplified by preamplifier (Preamp in Fig. 1) and then saved to the personal computer (PC in Fig. 1). Similarly, angular data were taken by goniometer and transferred to PC for saving after amplification to gonio-amplifier (Gonioamp in Fig. 1).

Furthermore, in the experiment continuous AE data had been taken. Therefore, several unwanted data like crypts noise, etc. were also saved together with acceptable AE data. Therefore, special filtering was applied for avoiding noise in AE saved data as well. All data were save in PC in which specially designed AE parameters analysis software based on MATLAB coding were used.
3. Experimental results and discussion

As already mentioned that four groups of participants joined to the experiments. These participants were grouped as young participants (20yrs. to 39yrs. old), middle aged participants (40yrs. to 59 yrs. old), old aged participants (60yrs. old and above), however, none of them were suffered from knee problems (according to the participant commitments); the last group of participants were patients who suffered from knee disease, like osteoarthritis. All participants joined the experiment based on basic declaration and procedures, however, several patients got special care in the experiment for their pain and cartilage damage conditions. The objectives of joining participants without pain were to identify the evaluation procedure of initial condition of cartilage damage, on the other hand, the objectives of joining knee patients to the experiments were to identify the evaluation procedure of damaged knee. Several biomarkers were selected to clarify, out of which two influential biomarkers, number of AE events and maximum amplitudes, were identified to clarify in the present paper as follows according to their significant characteristics in damage evaluation criteria.

3.1 Relative criterion of AE events acquisition

In the present experiments, total participants were 62. Total number of AE event in each cycle was defined in the present experiment as the total number of acquisition AE events in one cycle. Thus, total number of AE events for one participants were total number of acquisition AE events in five sets (total number in 3x5=15 cycles). Results of AE events for right knee of each participant are summarized in the present paper. The average results of each group are mentioned in Fig. 2 as A for young participants, B for middle aged participants, C for old aged participants and D for OA patients. It is seen in the figure that increasing age decreases the cartilage condition, that is, decreases the knee integrity with increases of age. Another observation is found in Fig. 2 that OA patients generates AE events almost double compared with other participants even with the old aged participants. Therefore, the relative acquisition criteria of AE events could be an influential biomarker in diagnosis of OA. Also results showed that old age participants generated double AE events compared with middle aged participants and same criteria were identified in the case of middle age with young participants. Although, this results were not filtered from noise generated from crypts noise. Furthermore, participants in each group were not the same numbers as well as results were not classified based on the gender...
criterion. Random selections of participants were done irrespective to their life style or sports activities. Present results represented the mid-level evaluations compared to the total evaluation technique as well.

Figure 2 Distribution of AE events based on age groups and patients.

3.2 Maximum amplitude criterion

Another influential biomarker was identified as the maximum amplitude distributions of AE events. Since according to the hypothesis, it is defined that damage of cartilage surface increases its surface roughness and thus increased AE event amplitude due to increasing elastic wave propagations. It is clearly identified in Fig. 3 that increasing age of participants, generates increasing maximum amplitude as well. Patients’ data represented the highest maximum amplitude while the young participants represented the minimum amplitude level.

Figure 3 Distribution of maximum amplitude based on age groups and patients
Although, the angular positioning of AE event distribution also showed the characteristic evidence of identifying the damage location of present diagnostic tool of AE technique, more complex evaluation criterion of damage location have been planned to be implemented. Diagnosis of OA patients as well all other AE data evaluation were clarified by orthopaedic specialist as well.

4. Conclusions

Knee joint integrity has been clarified in the present paper by continuous acquisition of AE imaging technique. Appropriate filtering has been applied for avoiding noise in continuous acquisition technique.

Two influential bio-markers for knee osteoarthritis (OA) diagnosis based on continuous AE imaging technique have been explained with experimental approach. One is mentioned as the relative criterion of AE events acquisition technique, and the another one is clarified based on maximum amplitude criterion. In AE events criterion bio-marker adaptive filtering was not adopted, although, in maximum amplitude technique filtering was applied. Since unwanted crypts noise biased the AE amplitude technique, adaptive filtering was useful to clarify the stable diagnosis bio-marker as well.

It was identified that statistical clarification of AE imaging is necessary for making the proposed AE imaging technique as a confident diagnosis bio-marker of joint osteoarthritis disease as well as of aging effects clarification on knee joint degeneration criterion indeed.

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