Evaluation of bone fracture in animal model using bio-electrical impedance analysis

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Summary Bone is a very strong, rigid protective organ of the animals which includes humans as well. They are found in different shapes and forms having complex internal and external structures. They are of prime importance as they provide the major locomotory structural and supportive elements to the animals. Bone fracture is very common occurrence these days due to different accidents and injuries. In clinical practice, generally doctors used to visually inspect X-ray images to determine the precise nature of fractures. The X-ray radiation exposure (particularly for multiple examinations) is unsafe and not good for health, and it is costly as well. This paper presents a simple and non-invasive technique of impedance measurement for detecting the bone fracture and for monitoring the bone fracture healing. The animal bone specimen (in this case buffalo) was obtained from local meat shop. The animal bone specimen was properly cleaned and wiped with cotton muslin cloth. The electrical impedance was measured by placing Ag–AgCl electrode on bone sample. The Ag–AgCl electrode pairs were connected to two channel BIOPAC system with MP 45 data acquisition unit. During the experiments, the bone fractures were manually produced. Different variations were observed in impedance values of normal, partially fractured and fully fractured bone. Based on experiment with animal bone, it was demonstrated that how the Electrical Impedance measurement by BIOPAC system can be used to assess the bone fracture and for monitoring the bone fracture healing in a non-invasive way. The changes in the electrical impedance of bone can act as a biomarker for monitoring bone fracture healing. Impedance of fractured bone and normal bone notify the healing of bone. © 2016 Published by Elsevier GmbH. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Large number of people across the globe suffers from bone fractures or injuries. It affects the victims tremendously in many ways. The worst affected part of the patient is quality of life followed by impact on socioeconomic condition,
personal costs, etc. The bones are very important for all human beings and animals to keep them moving and also help in protecting various soft organs of the body. Bones are very strong and rigid protective organs. They are found in different shapes and forms having complex internal and external structures.

About 206 bones are present in adult human beings which constitute approximately 18% weight of the human body (Evans, 1982). The behaviors of bones in vivo and ex vivo are different particularly with reference to measuring the electrical impedance (Gupta et al., 2013; Yoshida et al., 2009). A bone fracture is a medical condition in which there is damage in the continuity of the bone. Literature shows different techniques for detecting bone fracture and evaluation of healing process like ultrasound, X-ray radiographs, measurement of bone mineral density, quantitative computed tomography, acoustic emission, magnetic resonance imaging (MRI) and vibratory devices (Maffulli, 1999; Eyres et al., 1993; Markel et al., 1991; Hirasawa et al., 2002). X-ray and CT involve high level of radiation exposure (particularly when multiple examinations are done) which is very harmful especially for children and pregnant women, and it is costly as well. The electrical impedance measurement is a non-invasive and simple quantitative technique for evaluation of bone fracture healing (Hirashima et al., 2009; Yoshida et al., 2010). It has also been used very frequently for measuring physical properties and structure of substance in industries. Furthermore, it has been used for biological systems to measure body fat percentage, blood volume, movements of upper and lower limbs, etc. (Miyatani et al., 2001).

Materials and methods

Experimental setup

BIOPAC System with two channel MP45 data acquisition unit were used to determine the bio electrical impedance of bone at 50 kHz frequency. Basically 400 μA electrical current was injected in the bone specimen. MP45 was used as an A/D converter and a communicator with a computer. For this study, tibia bone of buffalo was employed. Before taking reading, the specimen was properly cleaned with cotton muslin cloth and placed on table. The electrical impedance was measured by placing two pair of self-adhesive Ag—AgCl electrodes/piezoelectric sensors on bone sample. The Ag—AgCl electrode pairs were connected to two channel BIOPAC system with MP 45. Fig. 1 shows the experimental set up used in this study.

Data acquisition

The electrical impedance values were recorded at 50 kHz under three condition viz. normal bone, partially fractured bone and completely fractured bone. Each condition of bone had given five trial each for 5 sec within a time gap of 10 min. Table 1 shows the recorded data during 5 trails. The bone was hit with a chisel to induce fracture.

Table 1 Mean impedance value recorded by BIOPAC system for normal, partially and completely fractured bone.

<table>
<thead>
<tr>
<th>Trials</th>
<th>Normal bone</th>
<th>Partially fractured bone</th>
<th>Completely fractured bone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>334.087</td>
<td>334.616</td>
<td>334.745</td>
</tr>
<tr>
<td>2</td>
<td>334.093</td>
<td>334.606</td>
<td>334.734</td>
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<tr>
<td>3</td>
<td>334.091</td>
<td>334.626</td>
<td>334.714</td>
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<tr>
<td>4</td>
<td>334.108</td>
<td>334.614</td>
<td>334.744</td>
</tr>
<tr>
<td>5</td>
<td>334.076</td>
<td>334.613</td>
<td>334.724</td>
</tr>
</tbody>
</table>

Results and discussion

The fluctuations in impedance values were observed for these three states of bone as shown in Fig. 2. The mean impedance changes recorded for 5 trial of normal, partially fractured and completely fractured bone were 334.091 ± .012 Ω, 334.615 ± .007 Ω and 334.732 ± .013 Ω, respectively as shown in Fig. 3. Specifically, the measurements permitted accurate and unambiguous distinction between the three conditions of bone: normal, partially fractured and completely fractured.

Figure 1 The set up for measuring electrical impedance of the normal bone as well as partially and completely fractured bones, respectively.

Figure 2 Measured impedance changes for three state viz. normal bone, partially fractured bone and completely fractured bone.
No study has been done so far on impedance analysis of buffalo bone. The experimental data presented here supports the concept that the bio-electrical impedance measurement can be used as an important tool for monitoring condition of bones like fracture healing process.

**Conclusion**

This study presents a simple and non-invasive technique of impedance measurement by using BIOPAC system. It monitors the bone condition based on recorded impedance value. The change in bio-electrical impedance values for different conditions of bone has been examined using an animal model. It has been observed that the electrical impedance of a normal bone is less than that of fractured bone. When the impedance value of fractured bone becomes same as that of normal bone during healing process, the fractured bone is considered to be healed. Therefore the bio-electrical impedance measurement conceivably can be used to reflect the condition and progress of fracture healing. Future work will focus on analysis of bone from different part of body.

**References**