A Novel Method of Fracture Detection Via Smartphone

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Statement of Purpose: Detection of fractures has traditionally been accomplished with plain film or digital radiography. An alternative screening technique of "ruling in" or "ruling out" fractures would be of benefit in clinical practice. An acoustic method of detecting fractures has been developed utilizing a smartphone-based platform. The aim of this study was to assess the accuracy of this system at detecting fractures of the foot and ankle compared to radiography.

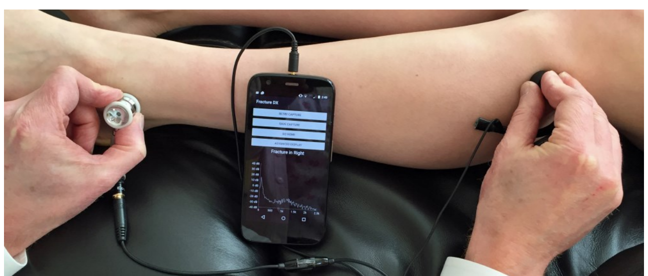
Literature Review

The use of sound waves to differentiate normal from fractured bones has been known since the early 20th century. Lippmann (1) first described a simple but non-quantitative technique for fracture identification though the use of a 128 Hz tuning fork and stethoscope. In this method, the examiner placed a stethoscope over a boney prominence at the end of a long bone and a vibrating 128 Hz tuning fork at the opposite end of the same bone. The examiner compared the sound of the bone on the presumably injured side to the same bone on the uninjured side. Experienced examiners were able to appreciate differences in the sounds of intact versus fractured bone. This simple test has been advocated for situations where x-rays are not available such as at sporting events (2) or in remote locations (3).

Since discovery of this technique, research in biomedical engineering, biomechanics, and orthopedics has produced many studies (4-14) evaluating bone density, fracture healing, prostheses loosening and joint mechanics through the application of vibration. Despite these advances in our understanding, no widely available, point-of-care instruments have made their way into clinical practice for the evaluation of fractures. Instead, clinicians continue to rely on standard radiographs as their default screening exam of choice. This practice continues in the face of mounting healthcare costs associated with overutilization (15) and the inherent risk that radiation exposure poses to patients and medical personnel (16).

Methodology

Six trauma patients selected from the author's practice were assessed with a novel acoustic fracture detection prototype system known as FractureDx (ScanDx, Orono, ME). All patients had a standard clinical work-up and treatment including x-rays. The prototype (Fig. 1), developed in conjunction with the University of Maine Department of Engineering and Computer Science, consisted of a smartphone (Moto G running Android ver. 5.1, Motorola, Chicago, IL) , microphone (EIM-001 microphone, Edutige, Soule, South Korea) with stethoscope attachment (standard pediatric cardiac bell attachment) and a single bone-conducting headphone (Aftershokz Sportz 3, East Syracuse, NY). A custom application (FractureDX app, ScanDx, Orono, ME) was developed to provide signal analysis. Right and left limbs were tested and compared in order to make a relative determination of the presence or absence of a fracture. If the total vibrational energy (dB/Hz) was found to vary more than 3.5 dB/Hz between the two sides, the lower value side was deemed to have a fracture. The clinical test protocol is described below.



FractureDx prototype (U.S. patent pending) being used on the fibula.

Test Protocol

1. With the FractureDx app running, the headphone is placed in contact with a boney prominence proximal to the fracture site.
2. The microphone/stethoscope attachment is placed distal to the fracture site.
3. A reading is taken on this limb by initiating a data capture on the app.
4. The same process is repeated on the contralateral limb using the same anatomic landmarks.
5. The app utilizing proprietary software analyzes the signals from the two captures.
6. If one of the captures is below the selected 3.5 dB/Hz threshold of vibrational energy (dB/Hz) compared to the other capture, the app diagnoses the lower value capture as a fracture.

Results

Demographic and experimental data from six patients is presented in Table 1. Patients 1-5 sustained radiographically-confirmed fractures and were correctly diagnosed by the prototype. Patient six sustained a contusion with negative radiographs and was not diagnosed with a fracture. Figures 3 and 4 demonstrate composite capture data from two fracture patients and their associated radiographs.

Table 1. Patient demographic and experimental data

	Patient 1	Patient 2	Patient 3	Patient 4A††	Patient 4B	Patient 5	Patient 6*
Age	75	67	55	51	51	62	49
Gender	m	f	m	f	f	m	f
Injury location	2nd digit	5th metatarsal	fibula	4th metatarsal	5th metatarsal	5th metatarsal	4th digit
Time since injury †	1d	1d	7d	3m	7d	9d	3d
Fracture on x-ray	positive	positive	positive	positive	positive	positive	negative
dB/Hz differential‡	10.78	18.09	6.56	9.88	16.13	13.18	0.78

* Patient 7 sustained a contusion with negative x-rays findings and did not meet the fracture threshold for FractureDx.
† Time since injury occurred until data capture.
‡ The differential between data captures on the injured and uninjured limb. A relative drop of more than 3.5 dB/Hz was considered indicative of fracture.
†† Patient 4 sustained two fractures occurring 5 months apart.

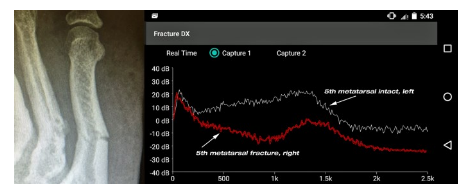


Fig. 3. 5th metatarsal fracture with data captures from bilateral 5th metatarsals.

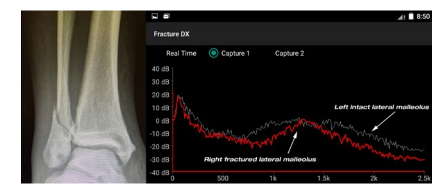


Fig. 4. Fibular fracture with data captures from bilateral fibulae.

Discussion

The results of this pilot study indicate that an acoustic-based technique of assessing bone integrity can correctly diagnose foot and ankle fractures in five patients with radiographically-confirmed fractures. Although the sample size was too small to achieve statistical significance, further studies with larger numbers cases are warranted given the results. Ideally, this study would include a number of negative case findings (i.e. no fracture present) such as was seen with patient six.

One drawback of this study was that the prototype required comparison test measurements between two limbs. This technique could potentially introduce variability reducing the diagnostic accuracy of the system. It is envisioned that future versions will use a reference database of normal bone signals for comparison to injured limbs.

In conclusion, although bone injury assessment is a critical aspect of trauma care, our methods of screening for fractures have failed to progress. Unfortunately, as medicine advances into the 21st century, there is a continued reliance on a 19th century technology with all its attendant shortcomings. The clinical benefits of a reliable, alternative screening method for fracture detection would be widespread. The prototype system disclosed may serve as the foundation for future development of such a point-of-care fracture screening instrument that is safe, mobile and cost-effective.

Conflict of Interest: Todd O'Brien, DPM is the owner of all intellectual property rights pertaining to the disclosed FractureDx prototype system and could financially benefit from its future commercialization.

References (see reverse)

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