# *Application of Sound for Bone Loss Detection*

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## ABSTRACT

Osteoporosis (OP) is a very difficult disease to diagnose due to the initial stages being asymptomatic. Usually, the bone disease is not diagnosed until extensive damage has already occurred. The purpose of this project was to explore a noninvasive method of detecting bone abnormalities in individuals through the application of sound waves. An extensive literature review was conducted of studies which explored the use of ultrasound and acoustic emission (AE) techniques.

## INTRODUCTION

Osteoporosis, or porous bones, is a metabolic condition in bones characterized by the loss of bone density, which drastically increases the risk of fractures (Curate, 2014). In 2015, an estimated ten million Americans suffered from OP and another 44 million showed a decrease in bone mineral density (National Osteoporosis Foundation, 2015). There are various stages of OP ranging from high bone density (far left) to osteopenia to a dramatic loss of bone mass, or severe OP (far right). The objective of this research was to determine if sound waves could be a potential method for the early detection of bone abnormalities.

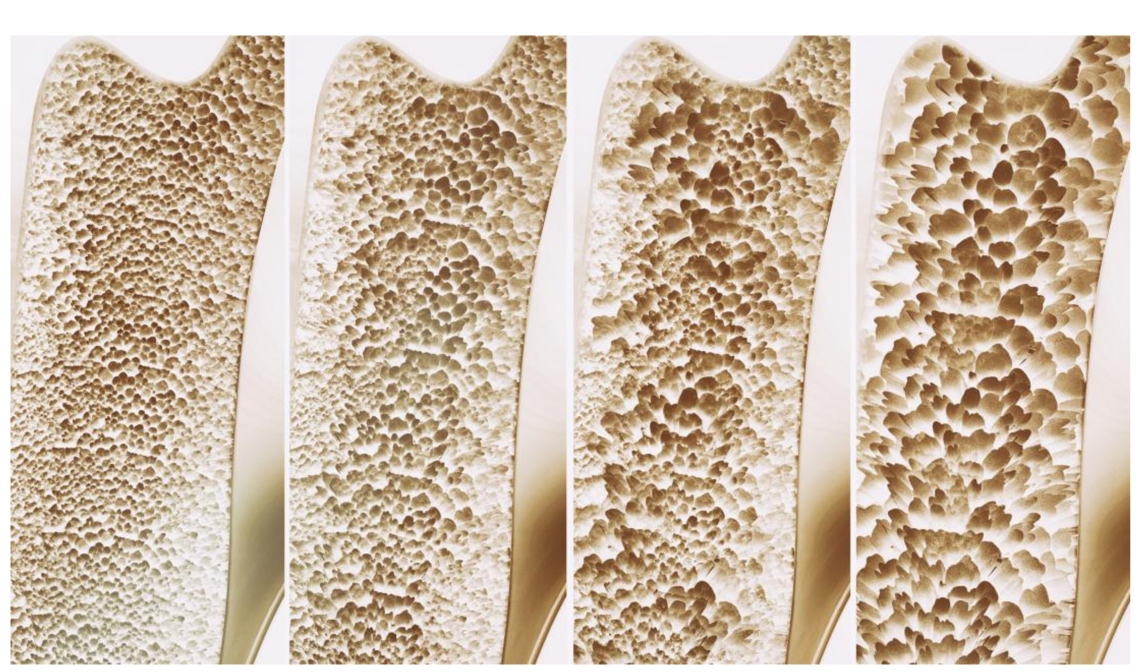


*Figure 1*. Progressive stages of OP. The leftmost image depicts normal bone density and the rightmost image depicts noticeable bone loss and increased porosity. Morrison, W. (2018). Adapted from medicalnewstoday.com

## METHODS

**Sound Wave Attenuation**

**Equation 1.** $A(x) = A_0 e^{-\alpha x}$

$A_0$ = amplitude of sound wave
$x$ = penetration depth
$\alpha$ = attenuation constant of material

**Impedance**

**Equation 2.** $Z = pv$

$Z$ = acoustic impedance of material
$p$ = volumetric density of material
$v$ = acoustic velocity

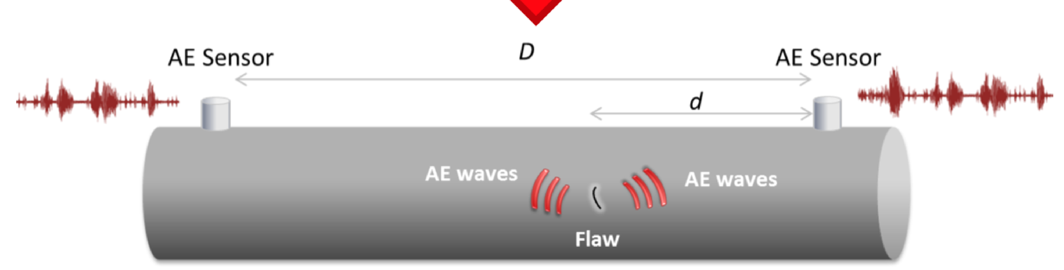
**Distance**

**Equation 3.** $d = \frac{1}{2}(D - \Delta T \times V)$

$d$ = distance from first AE sensor
$D$ = distance from emitting and receiving sensor
$V$ = wave velocity

## THEORETICAL APPROACH

**Sound Emission Technique**




**Identification of Abnormality**

**Diagnosis**

**Treatment**

**Medications** | **Diet** | **Resistance Exercise** | **Hormone Therapy**

*Figure 2*. Conceptual model of AE technique. (2016). Integrity Diagnostics.

## DISCUSSION

- This diagnostic approach involved the recording of deformation noise in bone to identify structural defects.
- Studies showed that both the amplitude distribution and pulse width distribution results of fresh bone clearly demonstrated characteristic spectra.
- AE was able to recognize when and where deformation took place as the structure was stressed.
- One denoted flaw of using sound, however, was the persistent presence of noise which is characteristic of sound devices.

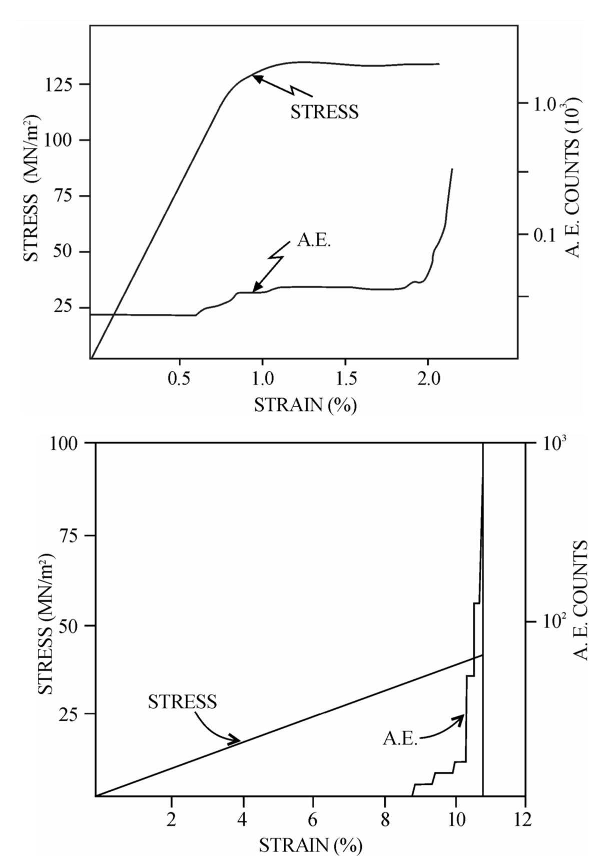



*Figure 3*. Graph of control specimen (top) and decalcified specimen (bottom) depicting stress v. strain and AE counts v. strain. Shrivastava, S., & Prakash, R. (2009). Adapted from JBSE

## CONCLUSIONS

- Studies determined that AE techniques proved to be highly sensitive to specimen damage.
- AE detected the presence of cracks even before visual detection.
- AE provided a real-time, non-invasive diagnostic technique.
- This technique could be used for the early detection of bone abnormalities such as fractures and OP.

## RECOMMENDATIONS

- One recommendation for future studies is to test different piezoelectric materials to determine the optimal substance for the detection of bone abnormalities.
- Further research in biomedical engineering is required to devise a sleek and ergonomic design to deliver the AE technique.
- This preliminary analysis of AE techniques for the biomedical field could be further applied to various industries such as Civil Infrastructure for the detection of leaks or cracks in gas or oil pipelines.

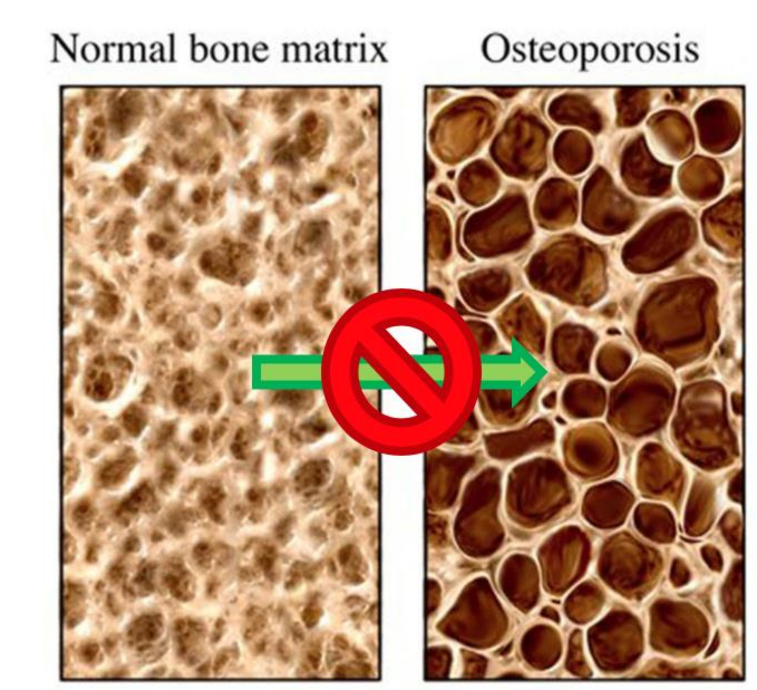



*Figure 4*. Comparison of normal bone matrix and osteoporosis. HealthJade. (2018). Adapted from healthjade.com

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