BONE DENSITY MEASUREMENT USING COMPTON SCATTERING

By

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This Work is Dedicated to
My Family

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ABSTRACT

The purpose of this project was to study and examine the applications of Compton scattering to measure bone mineral density and the relation between bone mass loss by aging and a disease called osteoporosis, which is, mostly a problem of post menopausal women. Out of many scientific applications of Compton scattering, bone mineral density measuring is also the most important.

In a Coherent/Compton scattering method for measurement of trabecular bone mineral density, the trabecular bone mineral density correlated well with the mineral density values obtained by the gamma ray transmission method. Many problems are encountered in the use of dual photon absorptiometry with a single detector. By measuring the ratio of coherent to Compton scattering it is possible to determine the effective atomic number of materials in the region appropriate for bone mineral estimation.

INTRODUCTION

Growth hormone (GH) plays an important role in skeletal growth. It increases bone turn over with a net increase in bone mass and periosteal appositional growth. Insulin like growth factor, produced by the liver has a unique property of stimulating bone formation. Parathormone has effects on both osteoclasts (supporting tissue- or cells that take calcium out) and osteoblast (bone-or cells that take calcium to bones) and is believed to have a positive effect on bone turn over and resorption. However, by human aging, the insulin growth factor (IGF -1) level falls below the adult normal range (600-800 nano-gram per Milliliter (ng/ml)) resulting in muscle and bone strength and energy decrease. This affects the continuity of building and retaining of bone mass.

Old human age is simply a state of hormonal deficiency, in that human growth hormone (HGH) which is a protein based polypeptide hormone that stimulates growth and cell reproduction and regeneration, will most likely decrease. Post menopausal women are especially prone to osteoporosis because they lack estrogen. Some effects of adult testosterone that plays key role in health as well as preventing osteoporosis may decline as testosterone levels decrease in the latter decades of adult life. So the aged human can not prevent the natural process of bone density loss. The decrease in bone mineral density in all men and mostly in women will cause a bone disease called osteoporosis.

Recently the sensitivity of the Compton scattering profile to the chemical compositions of the scatterer has been suggested as an alternative method of characterizing bone tissue by comparing the high energy tail of the Compton distribution with the region dominated by singly scattered Compton gamma- rays.

In the first chapter of this review, the physics of Compton Scattering and its applications are discussed. In the second chapter the review of literature on BDM and Osteoporosis is presented. Applications of Compton scattering to bone mineral density (BMD) measurements and diagnosis of osteoporosis are presented in chapter-3. The final chapter provide summary, conclusion and recommendations on the topics of Compton scattering applications.

CHAPTER 1

THE PHYSICS OF COMPTON SCATTERING

1.1 COMPTON SCATTERING IN PHYSICS

Compton scattering or the Compton effect is the decrease in energy (increase in wave length) of an X-ray or gamma-ray photon when it interacts with matter. It is the scattering of photons from charged particles named by the American Physicists Arthur Holly Compton, who was the first to measure photon electron scattering in 1922. Compton scattering occurs when the incident photon loses energy because of the interaction but continues to travel the material along an altered path. Energy and momentum are conserved in this process. The energy shift depends on the angle of scattering and not on the nature of the scattering material medium. Since the scattered photon has less energy, it has a longer wavelength and less penetrating than the incident photon. Is also important because it demonstrates that light can not be explained purely as a wave phenomenon. i.e. light must behave as if it consists of particles.

The interaction of Compton scattering takes place between the incident photon and an electron in the absorbing material. It is most often the predominant interaction mechanism for gamma-ray energies typical of radioisotope sources.

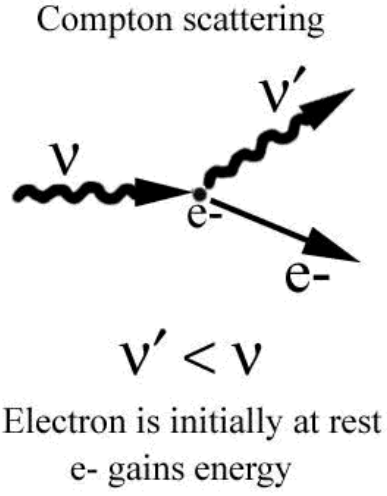

Figure 1.1: The Compton scattering of a photon

In Compton scattering, the incoming gamma-ray photon is deflected through an angle θ with respect to its original direction. The photon transfers a portion of its energy to the electron (assumed to be initially at rest), which is then known as a recoil electron, or a Compton electron. Because all angles of scattering are possible, the energy transferred to the electron can vary from zero to a large fraction of the gamma-ray energy (Wissmann, Wissmann).

A Compton interaction is one in which only a portion of the energy is absorbed and a photon is produced with reduced energy. This photon leaves the site of the interaction in a direction different from that of the original photon, as shown in fig.1.1. Because of the change in photon direction, this type of interaction is classified as a scattering process. In effect, a portion of the incident radiation "bounces off" or is scattered by the material (Wissmann, Wissmann).

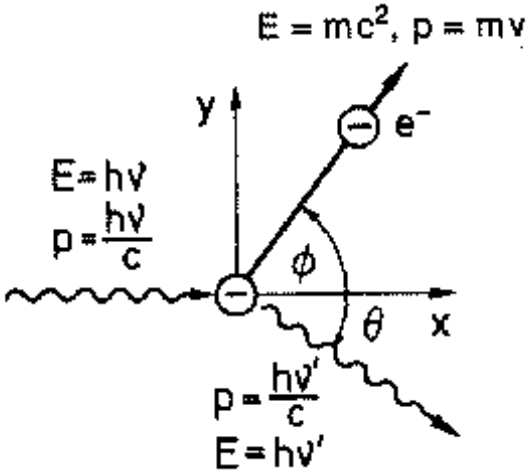

Figure 1.2: A photon of wavelength (λ) comes in from the left, collides with a target electron e at rest and a new photon of wavelength (λ′) emerges at angle Θ

The most significant object producing scattered radiation in an x-ray procedure is the patient's body. The portion of the patient's body that is within the primary x-ray beam becomes the actual source of scattered radiation. This has two undesirable consequences. The scattered radiation that continues in the forward direction and reaches the image receptor decreases the quality (contrast) of the image; the radiation that is scattered from the patient is the predominant source of radiation exposure to the personnel conducting the examination.

Compton scattering is the most influential and persuasive evidence for the existence of mass less photons as well as an inelastic, incoherent scattering of photons by atomic electrons but the origin of the effect can be considered as an elastic collision between a photon and an electron.

There can be single and double Compton scattering. The single Compton scattering is a single site in which events are tagged by coincidently detecting the scattered

photon with a second detector positioned at a defined angle. The contribution from single Compton scattering photons to the back ground in vivo X-ray fluorescence analysis is evaluated by taking in to account the energy broadening of the scattered photons which reflects the momentum distribution of the target electrons.

In double Compton scattering, a gamma-ray colliding with a free electron give rise to two scattered photons, in the majority of events the available energy is shared equally by the two photons. With this assumption Heitler and Nordheim show that the order of magnitude of the double process is smaller by a factor 137 than the single Compton scattering process.

Since, in double Compton scattering the incident photon interacts with an atomic electron and as a consequence two degraded photons and a recoil electron are emitted, this and other multiple Compton effects tend to be regarded as intrinsically quantum mechanical processes.

1.2 Inverse Compton scattering

Inverse Compton scattering is important in astrophysics. In X-ray astronomy, the accretion disk surrounding a black hole is believed to produce a thermal spectrum. The lower energy photons produced from this spectrum are scattered to higher energies by relativistic electrons in the surrounding corona. This is believed to cause the power law component in the X-ray spectra (0.2-10 keV) of accreting black holes.[9]

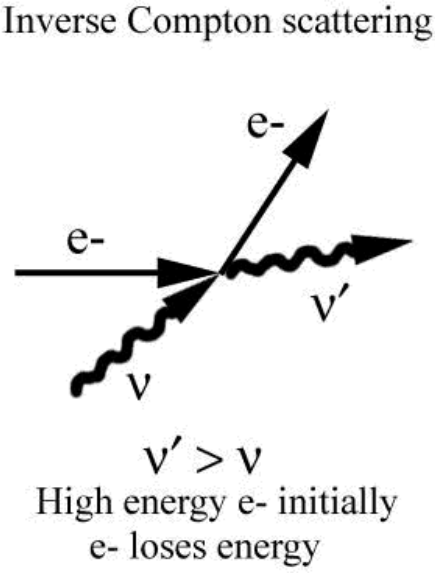

Figure 1.3: Inverse Compton Scattering

The effect is also observed when photons from the cosmic microwave background move through the hot gas surrounding a galaxy cluster. The CMB photons are

scattered to higher energies by the electrons in this gas, resulting in the Sunyael-Zeldovich effect. Observations of the Sunyaev-Zel'dovich effect provide a nearly redshift-independent means of detecting galaxy clusters. Some synchrotron radiation facilities scatter laser light off the stored electron beam. This Compton backscattering produces high energy photons in the MeV to GeV range subsequently used for nuclear physics experiments.

In Astrophysics inverse Compton scattering is more important than Compton scattering. It takes place when the electron is moving, and has sufficient kinetic energy compared to the photon. In this case net energy may be transferred from the electron to the photon.

1.3 Compton Scattering Formula: Derivation

Compton fired X-ray photons at stationary electrons and measured the increase in wave length of the scattered photons. The target electron were actually the valence electrons in the carbon atoms of a piece of graphite. He observed that the scattering of X-rays from electrons in a carbon target and found scattered X-rays with a longer wave length than those incident upon the target.

When a gamma-ray or x-ray beam is passed through matter the beam is to some extent scattered to the side; but in the process the frequency (and wave length) of the scattered radiation is changed. This is purely quantum mechanical effect that has no parallel in the classical theory of electromagnetic radiation. Classically the wave length of the scattered radiation should be exactly the same as that of the incident waves. When a photon collides with an electron, the electron recoils, taking some of the photons initial energy, and the photon that emerges from the collision is then, have less energy than the incident photon. Thus, the emerging photon (have less momentum) longer wave length from Planck's relationship

$$P = \frac{2\pi\hbar}{\lambda} = \frac{h}{\lambda} \qquad \text{where h is Plank's constant}$$

Figure 1.4 shows a γ photon with wavelength λ is directed at an electron e in an atom, which is at rest. The collision causes the electron to recoil, and a new photon γ' with wavelength λ' emerges at angle θ. Let e$'$ denote the electron after the collision. From the conservation of momentum,
In the X- direction:

$$\begin{aligned} \frac{h\nu}{c} &= \frac{h\nu' \cos\theta}{c} + p\cos\phi \\ &\Rightarrow h\nu = h\nu' \cos\theta + pc\cos\phi \\ &\Rightarrow h\nu - h\nu' \cos\theta = pc\cos\phi \end{aligned} \tag{1.1a}$$

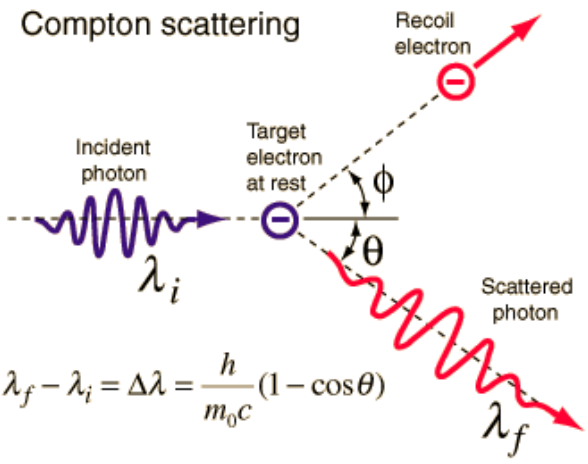

Figure 1.4: Compton scattering

squaring both sides of the above equation, we get,

$$h^2\nu^2 + h^2(\nu')^2\cos^2\theta - 2h^2\nu\nu'\cos\theta = p^2c^2\cos^2\phi \tag{1.1b}$$

In the y- direction

$$\begin{aligned} 0 &= \frac{h\nu'\sin\theta}{c} - p\sin\phi \\ &\Rightarrow h\nu'\sin\theta = pc\sin\phi \end{aligned} \tag{1.1c}$$

squaring both sides of the above equation, we get,

$$\Rightarrow h^2(\nu')^2\sin^2\theta = p^2c^2\sin^2\phi \tag{1.1d}$$

Adding equations (1.1b) and (1.1d), we get,

$$\Rightarrow h^2\nu^2 + h^2(\nu')^2 - 2h^2\nu\nu'\cos\theta = p^2c^2 \tag{1.1e}$$

From conservation of energy,

$$\Rightarrow h\nu + m_0c^2 = h\nu' + mc^2 \tag{1.1f}$$

But,considering relativistic case,

$$\Rightarrow m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{m_0 c}{\sqrt{c^2 - v^2}} \tag{1.1g}$$

$$\Rightarrow m^2 = \frac{m_0^2 c^2}{c^2 - v^2} \tag{1.1h}$$

Rearranging equation (1.1f), we get,

$$mc^2 = h(\nu - \nu') + m_0c^2 \tag{1.1i}$$

squaring both sides of the above equation, we get,

$$m^2c^4 = h^2(\nu - \nu')^2 + m_0^2c^4 + 2h(\nu - \nu')m_0c^2 \tag{1.1j}$$

Adding equations (1.1e) and (1.1j), and substituting the value of m^2, we get,

$$\begin{aligned}
&2h(\nu - \nu')m_0c^2 - 2h^2\nu\nu'\cos\theta - 2h^2\nu\nu' = 0 \\
&\Rightarrow 2h^2\nu\nu'\cos\theta - 2h^2\nu\nu' = 2h(\nu - \nu')m_0c^2 \\
&\Rightarrow 2h^2\nu\nu'(1 - \cos\theta) = 2h(\nu - \nu')m_0c^2 \\
&\Rightarrow \frac{h(1 - \cos\theta)}{m_0c^2} = \frac{(\nu - \nu')}{\nu\nu'} \\
&\Rightarrow \frac{h(1 - \cos\theta)}{m_0c} = \frac{c}{\nu'} - \frac{c}{\nu} \\
&(\lambda' - \lambda) = \frac{h(1 - \cos\theta)}{m_0c}
\end{aligned} \tag{1.1k}$$

Where, equation (1.1k) is the shift in Compton wave length, and λ= the initial wave length λ' =the wave length after scattering; h = the Planck's constant m_e =rest mass of the electron; c= speed of light and the term $\frac{h}{m_e c}$ is called Compton wave length for the electron.

Thus, the magnitude of the shift in wave length is related not to the Compton wavelength of the electron but to the Compton wavelength of the entire atom. The wave length shift $(\lambda' - \lambda)$ is at least zero (for θ=0^0) and at most twice of the Compton wavelength of the electron (for θ=180^0). The increase in wave length of an electromagnetic radiation, observed mainly in the X-ray and gamma ray region, on being scattered by material objects is caused by the interaction of the radiation with the weakly bound electrons in the matter in which the scattering takes place.

1.4 Applications of Compton Scattering

Since the Compton scattering process is strictly an interaction between a photon and an individual electron, in which, in the interaction the photon does not disappear, instead it is deflected through a scattering angle and parts of its energy is transferred to the recoil electron, there exists energy loss that depends up on the initial photon energy and the scattering angle. This variation of initial photon energy and the interaction between photons and electron by itself make Compton scattering process to play a great role in multi-directional scientific aspects. Such as measuring, detecting, examining and so on.

A Photon Scattering Mineralo-meter (PSM) can attain the best working conditions when it operates in a back scattering geometry mode. The large angle PSM device seems therefore to be very promising for trabecular bone mineral density (BMD)

measurements in vivo in peripheral anatomic sites. Bone density previously has been determined by counting the number of Compton and coherently scattered photons using incident radiation ^{241}Am (60 Kev). Now it has been improved by using more nearly optimal scattering angles and a higher incident beam energy. Because this improved technique is found to be clinically attractive in three-factors.

1. It is sensitive to changes in both BMD and elemental composition.
2. Elimination of attenuation corrections for overlaying structures is possible and
3. It has the ability to measure the axial skeleton.

Compton scattering is used to determine the effective atomic number (Z_{eff}) of composite materials of known composition such as brass, bronze, soldering materials etc. A practical method of calculating Z_{eff} was developed for the coherent to Compton scattering ratio (R) and the method is applicable for any material with known weight percentages of different elements in the compound. The coherent to Compton scattering ratio (R) depends only on the mixtures under study and provides a measurement of certain complicated functions of the atomic number Z and Z_{eff}. It is also known that the ratio(R) of the detected coherent and Compton scattering photons from bone can be used in order to determine its bone mineral density (BMD).

Compton scattering normalization method is described for the analysis of uranium bearing ore respect to the usage of K X-rays of uranium. Minimum backscatter energy is obtained at a scatter angle of 180^0 with fixed point source geometry and collimation in appropriate conclusions.

Gamma-ray Compton scattering is used for the detection of debonding in adhesively bonded composite aluminum joints when a collimated narrow beam of mono-chromatic photons, generated by a ^{137}Cs-source is directed toward the joint and scattered photons are recorded using a detector on the same side as the source.

A high energy Compton spectrometry is used for studies of electron momentum distributions with gamma-ray sources ^{198}Au and ^{137}Cs (i.e. more radiations is on heavy elements).

Laser Compton scattering (LCS) X-rays are used to measure the X-ray transmission in aluminum foils of different thickness.

Compton scatter telescopes have been largely experimental in design [2]. The most advanced and successful instrument is the so-called COMPTEL, which is typically two-level instrument [25]. In the top level, the cosmic gamma ray Compton scatters of an electron in a scintillator. The scattered photon then travels down into a second level of scintillator material which completely absorbs the scattered photon.

Photo tubes viewing the two levels can approximately determine the interaction points at the two layers and the amount of energy deposited in each layer.

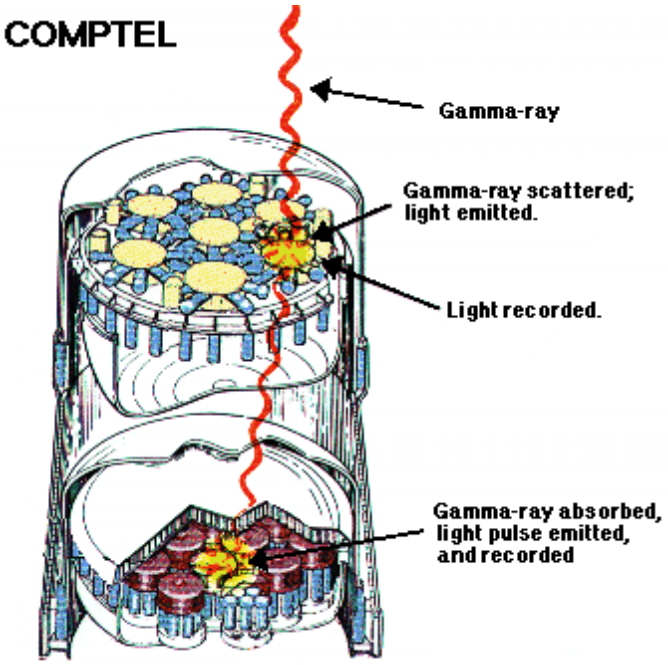

Figure 1.5: Compton Telescope

As shown in the picture above, the line between these two interaction points does not point back to the direction of the incoming Photon. It is possible, however, to determine the angle of incidence the cosmic photon made with respect to this line because the Compton scattering law provides for a definite relationship between this angle and the energy of the scattered photon (measured in the second level) and the scattering electron (measured in the first level).

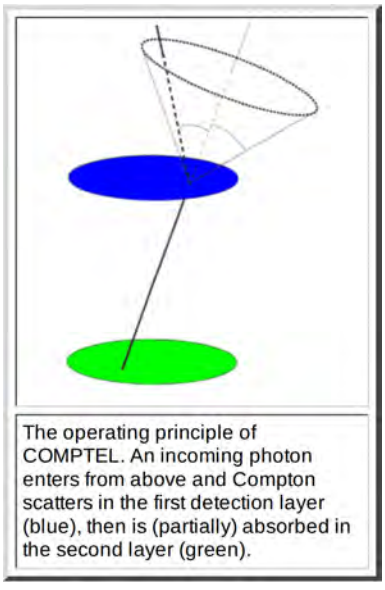

Figure 1.6: Compton Telescope,Operating principle.

In general, the Compton effect, often referred to as incoherent scattering is important in nuclear engineering (radiation shielding), in experimental and theoretical physics, in atomic and plasma physics, X-ray crystallography. In astrophysics, the region from about 1 to 30 Mev is a difficult, but interesting, part of the gamma ray astronomy energy range, this is the region where nuclear emission lines can be detected and a region where some pulsars and active galaxies are strongly detected. In addition it provides an important research tool in some branches of medicine, in molecular chemistry, and solid-state physics, and in the use of high energy electron accelerators and charged particle storage rings. In material physics Compton scattering can be used to probe the wave function of the electron in matter in the momentum representation.

Compton scattering is of prime importance to radio-biology as it happens to be the most probable interactions of gamma ray and high energy X-ray with atoms in living beings and is applied in radiation therapy.

CHAPTER 2

SURVEY of BONE MINERAL DENSITY (BMD) MEASUREMENTS

Measurement of the rate of fracture healing is a major problem in fracture research. Bone mineral density (BMD) of fracture callus has been used as a measure of healing in diaphyseal fractures. However, metaphyseal fractures (especially in the elderly) are now the commonest type of fracture and are a significant public health problem all over the world. Out of many countries several work on the field, few experiences are the following.

2.1 SPATIAL VARIATION OF OSTEOPOROSIS

2.1.1 United States of America

Osteoporosis costs 13.8 million dollars annually in the U.S.A. According to the National Random Survey of BMD reporting in the U.S.A (2009), the rapidly evolving technology of BMD testing has revolutionized the clinical care of osteoporosis; However, at present, there are no guidelines for BMD reporting.
In 1989, a subcommittee of the scientific Advisory Board of NOF described 4 clinical situations in which knowledge of the patients zone mass or fracture risk could affect clinical management decisions. The four diagnostic properties of decision rules are;
⇒ Simple Calculated Osteoporosis Risk Estimation(SCORE),
⇒ Osteoporosis Risk Assessment Instrument(ORAI);
⇒ Age, Body Size, No Estrogen (ABONE);
⇒ and body weight less than 70 kg (weight criterion). [8]
A survey was mailed to a random sample of bone densitometry centers in the U.S.A registered in the National Osteoporosis Foundation (NOF), which is an American voluntary health organization dedicated to osteoporosis and bone health, data base in order to evaluate the practice of BMD reporting. Fractured risk was reported by 70-percent of the centers and only the minority (less than15-percent) applied appropriate age and gender restrictions.

According to Bone Disease Program of Texas, Osteoporosis is a major health problem. Fractures of the spine or vertebral fractures occur commonly in men and women over the age of 60 and hip fracture remains a leading cause of death in elderly individuals. Repair and rehabilitation of hip fractures currently cost 15 billion dollars per year. Especially low bone mass leading to fractures remains a major health issue. The Surgeon General's report on osteoporosis issued in 2004, estimates One out of every two women over 50 will have an osteoporosis-related fracture in their life time, with risk of fracture increasing with age. Due primarily to the aging of the population and the previous lack of focus on bone health, the number of hip fractures in the United States could double or even triple by the year 2020.

According to a new research on Aquatic exercise and Bone density among post menopausal women, Osteoporosis is a bone disease common among women and almost 25 million people in the USA suffer from this disease, 80percent of them menopausal women. On studies focusing on the effect of water exercise on post menopausal women have not been unequivocal about its effect on bone density. It has been studied that whether water exercise can delay bone density loss among post-menopausal women of mean age 56 years old. In the experiment group members participated in water training program register no bone density loss, and might perhaps increase bone density by the end of study. While women that did not engage in any physical activity at all in the water training program, would manifest a decline in bone density. So exercise may be the most effective strategy to reduce osteoporotic fractures in older adults because of its potential to reduce both bone loss and fall risk. Bone density testing is strongly recommended if you: [26]

- are a post-menopausal woman and not taking estrogen.
- have a personal or maternal history of hip fracture or smoking.
- are a post-menopausal woman who is tall (over 5 feet 7 inches) or thin (less than 125 pounds).
- are a man with clinical conditions associated with bone loss.
- use medications that are known to cause bone loss, including corticosteroids such as Prednisone, various anti-seizure medications such as Dilantin and certain barbiturates, or high-dose thyroid replacement drugs.
- have type 1 (formerly called juvenile or insulin-dependent) diabetes, liver disease, kidney disease or a family history of osteoporosis.
- have high bone turnover, which shows up in the form of excessive collagen in urine samples.
- have a thyroid condition, such as hyperthyroidism
- have a parathyroid condition, such as hyperparathyroidism
- have experienced a fracture after only mild trauma.
- have had x-ray evidence of vertebral fracture or other signs of osteoporosis.

2.1.2 England

In 1990 on a paper Milk consumption and BMD in middle aged and elderly womenİ with objective To study the effects of the historical milk consumption on current BMD at the hip and spineİ, Commonly based on women aged 44-74 years recruited from four general practice in Cambridge, United kingdom in which Osteoporosis is an important public health problem and is the single most important cause of fractures in middle aged and elderly people. BMD at the hip and spine measured by dual energy X-ray absorptiometry results that milk consumption up to age 25 years were available for 252 women.

There was a consistent upward trend in BMD at all sites with increasing historical milk consumption. Milk consumption up to age 25 was a significant independent predictor of BMD at all sites in multiple linear regression analysis controlling for age,body mass index, menopausal status, smoking, ever use of hormone replacement therapy or oral contraceptives, physical activity and alcohol in take. It was concluded that, frequent milk consumption before age 25 favorably influences hip bone mass in middle aged and older women. Currently, it is estimated that there are about 190,000 fractures a year in the UK costing the National Health Service about 600 million pound. Prospective studies have shown that low bone density is an important predictor of future fracture risk. (Morgan et al., 1999)

2.1.3 Japan

Decreasing mortality and the low birth rates has resulted in a high rate of increase in the elderly population in Japan. Increases in osteoporosis and its complication (fractures) are inevitable among the Japanese elderly. The Ministry of Health and Welfare of Japan and other municipalities are in the process of developing standards for noninvasive and quantitative assessment of bone minerals in mass health examinations in order to prevent osteoporosis fracture in elderly females. Dual energy x-ray absorptiometry (DXA) has undergone development to significantly improve scan speed, image resolution and precision with relatively low exposure to x-rays, and is now considered one of the most suitable instruments to measure bone mineral density (BMD) in both clinical and mass-screening for osteoporosis in population-based mass health examinations in Japan. (Suzuki & Shibata, 994O) A study was made with title Relationship between total and regional BMD and menopausal state, body composition and life style factors in overweight Japanese women with objective to investigate whether menopausal state, body composition and life style factors influence total and regional bone mineral density in overweight Japanese women of average age 45 years(20-69 year). The result was that pre-menopausal group had significantly higher total body BMD as well as regional

BMD than post menopausal group. However, no difference in BMI percentage fat and fat mass(FM) were seen between the two groups. The multiple regression analysis stepwise method revealed that total and regional BMD correlated with menopause state and total FM independently.

Total and regional BMD did not correlated with total non-fat soft tissue mass (NFSM), energy in take, walking steps or physical fitness levels. Trunk and lower extremities BMD correlated with corresponding regional FM and NFSM, and upper extremities BMD correlated with only corresponding body part NFSM after adjusting menopausal state.

Total and regional BMD had strong negative correlation with menopausal state rather than total FM in overweight Japanese women. Weight bearing site BMD correlated with corresponding body part FM and NFSM and non-weight bearing site BMD only correlated with corresponding body part NFSM after adjusting for menopausal state.

The main cause of fractures is osteoporosis with bone mass or bone mineral content decrease. Bone mass is influenced by many lifestyle factors such as sex, aging, body weight, nutrition and physical activity. Overweight exerts mechanical stress on the bone and prevents aging-induced BMD decrease and fractures. However, only a few data are available concerning the BMD of Japanese overweight women.

Because the complications of decreased BMD, such as femoral neck fractures and severe spinal deformations, have a strong impact on daily life, prevention has become more important than therapy.

2.1.4 India

Osteoporosis is characterized by low bone mass with micro architectural deterioration of bone tissue leading to enhance bone fragility, thus increasing the susceptibility to fracture. Although exact numbers are not available, based on available data and clinical experience, on estimated 25 million Indians may be affected. Osteoporotic fractures in India occur commonly in both sexes, and may occur at a younger age than in the West. Recently published data have clearly demonstrated widespread vitamin D deficiency across India, at all ages and in both sexes, particularly in the urban areas. Poor sunlight exposure, skin pigmentation and a vitamin D-deficient diet are some obvious causes for this finding. Indians have low BMD as compared to the western Caucasians. This could be attributed to differences in skeletal size; however, the high prevalence of vitamin D deficiency is a major factor in the low BMD and poor bone health of Indians. Healthy lifestyle (diet, exercise and sunlight exposure) can have a major positive impact on the bone metabolism and bone health of Indians. (Malhotra & Mithal, 2007)

How common is Osteoporosis in India? (Malhotra & Mithal, 2007) Osteoporosis in India has had relatively little attention until recently. We do not have a clear data as of how many of our people has osteoporosis but it is likely 30-40-percent of people above the age of 50 years in India has it. Also this is happening around 10 years earlier than people in the west. In the west women are more affected but it seems in India it is equally common in men.

2.1.5 Ethiopia

Osteoporosis is a chronic disease characterized by low bone mass and deterioration in the micro-architecture of bone that increases its susceptibility to fractures. We set out to evaluate the prevalence of osteoporosis among Ethiopian immigrant and Israeli-born women and to determine the risk factors.

A cross-sectional study among 181 Ethiopians immigrants and 98 Israeli-born women. Hip, forearm and spinal bone mineral density (BMD) were measured. Risk factor information was obtained from an interview. BMD and osteoporosis rates were compared between the groups.

We defined 38.7-percent Ethiopian and 5.2-percent Israeli-born women as having osteoporosis. Rates of low BMI, prolonged lactation, age at first giving birth and sunlight exposure were higher in Ethiopian women compared to the Israeli-born. As conclusions the prevalence of osteoporosis among Ethiopian immigrant women living in Israel is extremely high compared to national and international rates. Therefore, we suggest that an immediate prevention program among Ethiopian women be started and guidelines for care-givers be developed, in order to raise their awareness for osteoporosis.[27]

2.2 World Health Organization (WHO)

In 1994, an expert panel convened by the World Health Organization (WHO) developed diagnostic criteria for osteoporosis and reduced bone density in white women. Two levels of reduced BMD were defined as Osteopenia, which is a mild reduction in BMD and Osteoporosis, which is a more severe reduction.

The first nationally representative data on BMD of the hip were collected in the 3rd National Health and Nutrition Examinations Survey (NHANES III) (1988-94) [5]. The BMD data were collected using DXA. Estimates of the concerning the definition of low bone density in groups other than white women: however it is clear that Osteoporosis is not solely a disease of white women. The classification of normal BMD, osteopenia with a z-value (Z-score$<$ -1) and osteoporosis,(Z score$<$ 2.5) is based on WHO criteria.

The BMD of calcaneous were measured in 197 Okinawa female aged 40-80 years with type-2 (non-insulin dependent) diabetes, and 249, age matched non-diabetes female were selected as control group. The BMD was decreased with age in both diabetes and control group. The difference between subject and control group were not significant except for the age group of 70s the level being higher in diabetes groups. These findings suggest that the diabetic osteopenia is not specific complication in calcaneous of type-2 diabetic female.

Bone mineral deficits have been reported after treatment for a variety of pediatric malignancies and represent morbidity that can be reduced or prevented through life style changes and attention to other common cancer-related sequel such as hypogonadism.

A study, through International Bibliographic Information, on Dietary supplements on a title Bone mineral density measured by dual-energy X-ray absorptiometry and novel markers of bone formation and resorption in patients on anti-epileptic drugs. In such patients on anti-epileptic drugs, bone loss has been mainly demonstrated at radial sites (of age 24-49 men and women) using old technology and has been ascribed to drug induced vitamin-D deficiency rather than to any direct effects of the treatment on bone cells.

The WHO guidelines formed the bases for defining osteoporosis based on levels of low bone mass in patients who have not yet suffered fracture based on DXA of the spine and femoral neck, and single photon absorptiometry (SPA) of the forearm. These guidelines on BMD measurement are best defined for Caucasian post menopausal women in whom the risk of osteoporosis is greatest. DXA is the gold standard and the only BMD technology for which WHO criteria for diagnosis of osteoporosis originally for post menopausal Caucasian women over age 65 can be used.

2.3 Summary Of Literature Review

Generally, many studies have demonstrated significant differences in bone mineral density between various racial groups (Tobias et al., 1994). In any general population anywhere in the world, everything being the same, the biggest risk is genetic. A large number of those affected-may be three-fourths-inherit it.

Osteoporosis is a major public health problem, affecting millions of people worldwide. The associated health care costs are growing in parallel with increases in elderly populations, and it is expected that the number of osteoporotic fractures will double over the next 50 years. The best way to address osteoporosis is prevention. (Chan et al., 2003)

There are huge ethnic differences. In the United States, Afro-Americans have a relatively lower incidence than Caucasians. The Chinese have a slightly higher incidence. Asian women have been reported to have lower bone mineral density (BMD) than Caucasians, but this could be due to body habitus rather than ethnicity. In South Africa the prevalence of osteoporosis is much higher in whites than in blacks. This is surprising, since factors that might predispose to reduce bone mass are more preponderant in black communities. A study in Europe showed the incidence of hip fracture to be very high in the Scandinavian countries compared to those in the Mediterranean nations. The difference was very big. In Europe, women have two-three times higher risk of hip fracture compared to men. In such places as Turkey, the incidence is low and the risk the same between men and women. We do not know why. So a man in a Scandinavian country has a higher risk of a hip fracture than a woman in Turkey and we have no explanation as yet for this (Krishnakumar, 2004).

Selected facts and statistics about osteoporosis and its impact in- General (world wide) (**?**)

- Osteoporosis affects an estimated 75 million people in Europe, USA and Japan.
- 1 in 3 women over 50 will experience osteoporotic fractures, as will 1 in 5 men.
- Osteoporosis takes a huge personal and economic toll. In Europe, the disability due to osteoporosis is greater than that caused by cancers (with the exception of lung cancer) and is comparable or greater than that lost to a variety of chronic noncommunicable diseases,such as rheumatoid arthritis, asthma and high blood pressure related heart disease.
- Although low BMD confers increased risk for fracture, most fractures occur in post-menopausal women and elderly men at moderate risk.
- In women over 45 years of age, osteoporosis accounts for more days spent in hospital than many other diseases, including diabetes, myocardial infarction and breast cancer.
- Evidence suggests that many women who sustain a fragility fracture are not appropriately diagnosed and treated for probable osteoporosis.
- The great majority of individuals at high risk (possibly 80-percent), who have already had at least one osteoporotic fracture, are neither identified nor treated.
- An IOF survey, conducted in 11 countries, showed denial of personal risk by post-menopausal women, lack of dialogue about osteoporosis with their doctor, and restricted access to diagnosis and treatment before the first fracture result in under diagnosis and under treatment of the disease.

- In any general population anywhere in the world, every thing being the same, the biggest risk is genetic.
- The most severe osteoporotic fracture is that of the hip. It is estimated that about 1.7million hip fractures occured world in 1990.
- Bone mass is greatest in those of African heritage, who have the lowest fracture rate, and is least in Caucasian women of Northern European extraction, who have the highest fracture rate.

CHAPTER 3

BMD MEASURING USING COMPTON SCATTERING

3.1 WHAT IS BONE MINERAL DENSITY (BMD) ?

Normal bone is composed of protein, collagen and calcium all of which give bone its strength. There are two major types of bone. Cancellous bone (also known as trabecular bone) is the inner, softer portion of the bone, and cortical bone is the outer, harder layer of bone. Bone is constantly being remodeled. This is the natural, healthy state of continuous uptake of old bone (resorption) followed by the deposit of new bone. The cells that lay new bone down are called osteoblasts, and the cells responsible for resorption of old bone are called osteoclasts. Osteoporosis occurs as a result of a mismatch between osteoclast and osteoblast activities. This mismatch can be caused by many different disease states or hormonal changes, aging, with diets low in calcium and vitamin-D. [12]

Measuring bone mass and bone mineral density is a common part of managing Osteogenesis Imperfecta (OI) in children and adults. Bone mass refers to the weight of the skeleton. Bone density refers to the ratio of weight to the volume or area of the bones. The basic idea is that heavier bones will be stronger bones. The child or adult,s age, height and degree of physical maturity are important factors in measuring and understanding bone mineral density (BMD). When information about bone mineral density is combined with personal and family medical history, findings on physical examinations, x-rays and biochemical testing, doctors can get a more complete picture of the child or adults bone health. [12]

Bones naturally become thinner (called osteopenia) with aging, because existing bone is broken down faster than new bone is made. As this occurs, our bones lose calcium and other minerals and become lighter, less dense, and more porous. This makes the bones weaker and increases the chance that they might break (fracture). With further bone loss, osteopenia leads to osteoporosis. So the thicker your bones are, the longer it takes to get osteoporosis. Although osteoporosis can occur in men,

it is most common in women older than age 65.

3.2 How To Increase Bone Mineral Density (Bone Mass)

If our bone density is lower than normal, we can take steps to increase our bone strength and reduce our chances of having a fracture. Some ways to increase bone density and strength include combining calcium and vitamin D supplements with weight -bearing exercise (such as walking), weight training (such as lifting weights or using weight machines, and using medicines such calcitonin (Miacalcin) (alendronate) (Fosamax) or risedronate Actonel). After menopause, women can use hormone therapy and raloxifene (Evista) to increase bone density. The majority of people with OI have low bone density. It is a major reason for the skeletal fragility and frequent broken bones seen in this disorder. To increase our bone mineral density; Let us $\star$ Optimize our nutrition. A calcium supplement is not enough. A healthy diet will supply some of the nutrition we need, and medical-grade nutritional supplements can fill any gaps.

Alkalize our diet Some foods create acid in the body which must be buffered by the alkalizing compounds contained in bone. Avoid meat, sugar and coffee (they are acid-forming) and eat more vegetables, fruit and nuts (they alkalize).

Focus on fitness Exercise at least 30 minutes, three times a week. Weight-bearing exercise is the most helpful for our bones

Consider the emotional foundation Stress, worry, and anxiety produce high levels of cortisol, which is destructive to bone. Reducing stress levels through cognitive therapy or other methods can only benefit our bone health.

Health Tests Consider other bone health tests to get a more rounded perspective of our bone health.

3.3 Why is Bone Mineral Density Measurement Important ?

The only sure way to determine bone density and fracture risk of osteoporosis is to have a bone mass measurement (also called bone mineral density or BMD test). Test results will help us and our doctor decide the best course of action for our bone

health. A bone mineral density (BMD) test measures the density of minerals (such as calcium) in our bones using a special x-ray or computed tomography CT scan. This information is used to estimate the strength of our bones. A bone density test is a fairly accurate predictor of our risk of fracture. It uses a low dose of radiation in a simple and painless way to measure bone mass. Bone mass can be measured in the total body or in specific regions of the skeleton such as the spine; hips; legs and arms. These specific sites are chosen because they are easily accessible, or places likely to fracture. The amount of bone at each site is one of the factors that determine how much trauma or force it can withstand before it breaks.[12] The most common method for measuring bone mass is called Dual Energy X-Ray Absorptiometry, or DXA [12]. The DXA instrument does not enclose the person but does require holding still for approximately 60 seconds. In the Central DXA examination, which measures bone density in the hip and spine, the patient lies on a padded table. An x-ray generator is located below the patient and an imaging device, or detector, is positioned above. The DXA bone density test is usually completed within 10 to 30 minutes, depending on the equipment used and the parts of the body being examined. To measure bone mass with a DXA machine, the person lies on a flat padded table and remains motionless while the armİ of the instrument passes over the whole body or over selected areas. While the measurement is performed, a beam of low-dose x-rays from below the table passes through the area being measured. These x-rays are detected by a device in the instrumentŹs arm.İ The machine converts the information received by the detector into an image of the skeleton and analyzes the quantity of bone in the skeleton. The results are usually reported as BMD, or bone mineral density,İ the amount of bone per unit of skeletal area. Each measurement takes less than a minute to perform. For a total body measurement, which provides individual measurements of the legs, the trunk, the pelvis, the ribs, the arms and the skull, the person simply lies flat and motionless. Besides DXA, bone mineral density can also be measured using other types of equipment. Getting a measurement of BMD can:

• Provide additional information when there is x-ray evidence of low bone mass.

• Provide information about skeletal development in children with OI.

• Provide a measure for evaluating the effect of reduced physical activity.

• Provide a measure for studying the effect over time of different types of treatments including medical treatments and rehabilitation and exercise programs. It may be used as guide for starting and/or stopping a treatment.

3.4 Different Ways to Measure BMD.

There are several ways to measure bone mineral density; all are painless, noninvasive and safe and are becoming more readily available. In many testing centers we

don’t even have to change into an examination robe. The tests measure bone density in our spine, hip and/or wrist, the most common sites of fractures due to osteoporosis. Our bone density is compared to two standards, or norms, known as "age matched" and "young normal." The age-matched reading compares our bone density to what is expected in someone of our age, sex and size. The young normal reading compares our density to the optimal peak bone density of a healthy young adult of the same sex. The information from a bone density test enables our doctor to identify where we stand within ranges of normal and to determine whether we are at risk for fracture. In general, the lower our bone density, the higher our risk for fracture. There are several different machines that measure bone density[11]. Central machines measure density in the hip, spine and total body. Peripheral machines measure density in the finger, wrist, knee cap, shin bone and heel.

3.4.1 Dual-energy X-ray absorptiometry (DEXA).

Dual-energy x-ray absorptiometry (DEXA) technology was introduced in 1988 and has become the most popular tool for measuring bone density. This is the most accurate way to measure BMD. It uses two different X-ray beams to estimate bone density in your spine and hip. Strong, dense bones allow less of the X-ray beam to pass through them. The amounts of each X-ray beam that are blocked by bone and soft tissue are compared to each other. DEXA can measure as little as 2-percent of bone loss per year. It is fast and uses very low doses of radiation. Single-energy X-ray absorptiometry (SXA) may be used to measure heel and forearm bone density, but SXA is not used as often as DEXA.

3.4.2 Peripheral dual-energy X-ray absorptiometry (P-DEXA).

P-DEXA is a type of DEXA test. It measures the density of bones in the arms or legs, such as the wrist-it cannot measure the density of the bones most likely to break, such as the hip and spine. P-DEXA machines are portable units that can be used in a doctor’s office. P-DEXA also uses very low doses of radiation, and the results are ready faster than standard DEXA measurements. P-DEXA is not as useful as DEXA for finding out how well medicine used to treat osteoporosis is working.

3.4.3 photon absorptiometry (DPA).

This test uses a radioactive substance to measure bone density. It can measure BMD in your hip and spine. DPA also uses very low doses of radiation but has a slower scan time than the other methods.

3.4.4 Quantitative computed tomography (QCT).

This is a type of CT scan that measures the density of a bone in the spine (vertebra). A form of QCT called peripheral QCT (pQCT) measures the density of bones in your arms or legs, usually your wrist. QCT is not usually used because it is expensive, uses higher radiation doses, and is less accurate than DEXA, P-DEXA, or DPA.

SPA (Single Photon Absorptiometry) :- measures the wrist (used infrequently);

RA (Radiographic Absorptiometry) :- uses an X-ray of the hand and a small metal wedge to calculate bone density;

QUS (Quantitative Ultrasound) :- uses sound waves to measure density at the heel, shin bone and kneecap.

SXA (single Energy X-ray Absorptiometry) :- measures the wrist or heel;

3.5 Osteoporosis, A Bone Disease

Osteoporosis is a bone disease common among women and it constitutes one of the dominant factors reducing quality of life and even shortening life span. The reason for the higher frequency of the disease with old age is attributable to the fact that as women age, the monthly period ceases and a gradual process of bone density loss commences, which may lead in the final analysis to fractures of spinal vertebrae,hip and wrist bones.

Metabolic bone diseases such as osteoporosis is characterized by progressive loss of bone mass often resulting in fracture after minimal trauma, lead to loss of bone minerals from both compact and trabecular bones, which eventually leaves the affected bone vulnerable to traumatic fracture. The bone mineral density of the mandible is quite useful to study bone resorption after tooth loss and to determine the relationship between mandibular and skeletal bone mineral density. Medical diagnostic techniques based on gamma rays scattering are relatively new and many are still under development. The combined use of coherent and incoherent scattering at gamma ray energies <100 keV has been proven quite useful, particularly in relation to osteoporosis.

Throughout the life, old bone is removed (resorption) and new bone is added (formation) to the skeleton. During childhood and teenage years, new bone is added faster than old bone is removed. As a result, bones become larger, heavier, and denser. Bone formation continues at a pace faster than resorption until maximum bone density is reached at around the age of 25 years. After that age, bone resorption slowly begins to exceed bone formation. Bone loss is most rapid in the first few years after

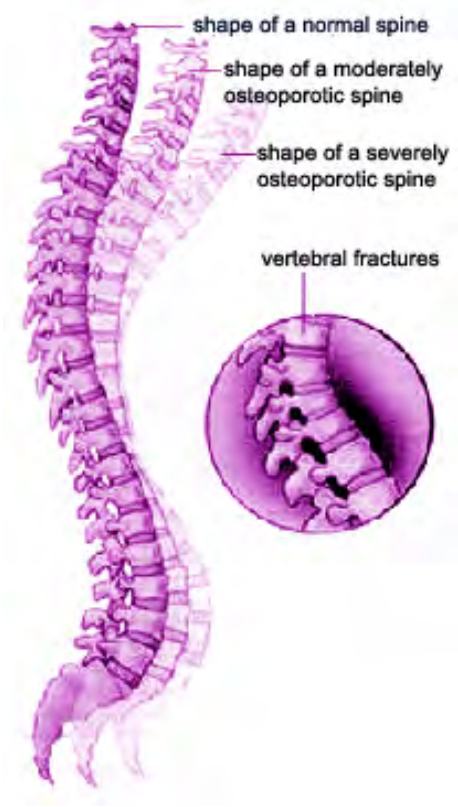

Figure 3.1: Osteoporosis in Bones[10],Vertebral Fracture

menopause. Osteoporosis develops when bone resorption occurs too quickly or if replacement occurs too slowly.

3.5.1 What are the symptoms of osteoporosis? (Krishnakumar, 2004)

Absolutely nothing until you break a bone. It is something like cholesterol, which can be high but you have no symptom until you have a heart attack or you drop dead. Declining estrogen have long been linked to osteoporosis, but bone density starts to decline years before these levels drop according to Dr. Joseph Cannon, Kellet Chair in Allied Health Sciences and Principal Investigator of the National Institute of Aging funded study.

3.5.2 Who are at risk for Osteoporosis?

Certain factors are linked to the development of osteoporosis or contribute to an individual's likelihood of developing the disease. These are called "risk factors." Many people with osteoporosis have several of these risk factors.

Factors determining peak bone mass are genetic and non genetic (nutrition,smoking,

Table 3.1: Risk Factors Associated With Development of Osteoporosis[23,22]

Aged on both sexes	Menopause in women
Low body weight	Excessive alcohol intake
Family history of osteoporosis	Estrogen-deficient states
Nulliparity	Sedentary lifestyle
Calcium-deficient diet	Thyroid hormones
Use of medications	Use of steroid/ drugs/
Lack of physical activity	Smoking

exercise, hypogonadism).

3.5.3 How can it be diagnosed? (Krishnakumar, 2004)

Osteoporosis is diagnosed by the measurement of bone mineral density. The test needed is a special test of bone called bone mineral density (BMD) scan which measures the density of spine, wrist and hip bones (the most common sites of fractures). These tests are painless, noninvasive and safe.

DEXA measures the bone mineral content (BMC) of the spine, hip, wrist, femur, or any other selected part of the skeleton. It does this by focusing an x-ray on a body site and measuring the proportion of light rays that pass through the tissue as opposed to being blocked by minerals in the bone. Using computer software, it then divides that number by the surface area of the bone being measured to create bone mineral density (BMD). (Chan et al., 2003)
Sometimes it can be seen on an X-ray when there is a lot of bone loss. Then there are techniques such as bone densitometry, with which the density of the bones can be measured. This gives a good index of the risk. We measure the bone density and find out how far it is away from normal ones. About every 10 per cent away from the normal, the risk of fracture doubles; 20 per cent away, the risk is four times; 30 per cent away, the risk is eight times; and so on. So, the risk increases dramatically as the quality of bones decreases. (Krishnakumar, 2004)

3.6 BMD Measurement with Coherent to Incoherent Scattering Ratio Method.

Dual-energy x-ray absorptiometry (DXA) is recognized as the reference method to measure bone mineral density (BMD) accurately and reproducibly. The World Health Organization (WHO) has established DXA as the best densitometric technique for assessing BMD in post-menopausal women and based the definitions of osteopenia and osteoporosis on its results (table I). DXA allows accurate diagnosis of osteoporosis,

estimation of fracture risk, and monitoring of patients undergoing treatment. [20]

In this context, various bone density-measuring methods are available and coherent to incoherent scattering ratio method is a typical one. In one study, measurements were made to study the variation of Rayleigh to Compton scattered intensity as a function of K_2HPO_4 and KI concentration in water (simulating the mandibular bone density and kinetics of thyroid iodine respectively) for 59.54 and 145 keV incident gamma rays, respectively. The scattered gamma rays are detected by a high-resolution HPGe semiconductor detector. The experiments are performed for different concentrations ofK_2HPO_4 and KI in distilled water. The observed intensity ratio of Rayleigh to Compton scattered gamma flux, corrected for photo-peak efficiency of the HPGe gamma detector and absorption of photons in the target and air is determined for various concentrations. (Sharma et al., 2009)

This technique was developed for the determination of trabecular bone mineral density in the distal radius. The method is based on measurement of the intensity ratio coherently and Compton scattered photons using a ^{241}Am radionuclide as a radiation source and a semiconductor crystal as the detector. This ^{241}Am source has the potential for measuring both trabecular bone mineral density and average fat/muscle ratio in a tissue volume, with a low absorbed dose to the subject. A good correlation was observed between bone ash and the coherent / Compton scattering ratio. The trabecular bone mineral density correlated well with the mineral density values obtained by the gamma transmission method.

The aim of the work reported here was to investigate the feasibility of using a gamma-ray scattering technique to give a measure of mandibular bone density. Both measurement precision and linearity versus density have been assessed. Potentially, such a technique offers a low dose, compact and relatively inexpensive means of indicating mandibular bone density compared with DXA and QCT. Gamma-ray Scattering techniques have been previously used or investigated for the measurement of BMD in the heel as a predictor of skeletal osteoporosis. (Sharma et al., 2009)

3.6.1 Theory of Coherent and Incoherent Scattering

Theoretically, each gamma ray interaction process could be used as the basis for a noninvasive assessment of mandibular bone density and the stable iodine content of tissue. In scattering experiments, for a gamma ray flux impinging on a target (phantom in the present study), there is significant probability for coherent (Rayleigh) scattering to occur in addition to well-known incoherent (Compton) scattering. In the observed scattered spectra originating from interactions of primary gamma ray flux with the phantom under study, there are two peaks in the observed scattered

spectra, a full-energy peak resulting from coherently scattered gamma rays and other a broader peak of lower energy representing secondary gamma rays that have suffered energy loss after scattering in the target material, and are referred to as Rayleigh (coherent or elastic) and Compton (incoherent or inelastic) peaks, respectively, in gamma ray spectroscopy. [12]

Rayleigh (or elastic) scattering is the process in which the scattered gamma ray has the same energy as that of incident gamma ray, and is predominant at low incident gamma ray energies, small scattering angles and high atomic number of the target. A number of workers have proposed or used the measurement of the ratio of coherent to Compton scattered photons from irradiated bone or other tissues to determine information on the composition of that tissue. Because coherent scatter is very dependent on the atomic number of the scatterer, the ratio of coherent to Compton scatter is also dependent on the atomic number of the scatterer, varying approximately as Z^2. Similarly the coherent/Compton scattering ratio of a composite material, such as bone, containing many elements, is dependent on the atomic numbers of its component elements and their proportion in the material.

The coherent to incoherent scattering intensity ratio method has been quite successful in various fundamental and medical applications of gamma radiations. Morgan, have applied this technique to measure mandibular bone density by observing the scattered spectrum from solutions of K_2HPO_4 in distilled water, a phantom simulating the mandibular bone, but the work is limited to scattering angle of 150^o only. They have also applied this technique for fat fraction measurement. Puumalainen have successfully applied this technique for the qualitative assessment of soft-tissue iodine content, but the study is limited to scattering of 59.54 keV gamma photons at scattering angles of 45^o and 90^o. More recently, Singh have used this non-destructive technique for assigning effective atomic number to composite materials of industrial and scientific interest (Morgan et al., 1999).

It has been verified that radiation scattered from the source collimator opening do not reach directly the active volume of HPGe detector, and the background near the detector assembly comes to natural background level in the laboratory when source window is closed. In the present measurements, the Canberra HPGe detector and electronic modules (power supply and amplifier) are used, and the experimental data are accumulated on a PC-based ORTEC Mastreo-32 Multichannel analyser (MCA). The observed scattered spectra provide Rayleigh to Compton intensity ratio, for each angular position of the detector, for each of the solutions simulating mandibular bone/kinetics of thyroid iodine.[21]

3.6.2 Experimental arrangement

The experimental arrangement is shown schematically in Fig-3.2. Backscatter geometry was chosen for compactness and ease of set-up. A7.4 GBq ^{241}Am source (5 mm diameter sphere) was collimated using a 5 mm diameter lead cylinder. A 32 mm diameter, 10 mm depth hyper-pure germanium detector recorded the scattered photon spectrum. A 10 mm thick steel sleeve was fitted over the detector housing with a central 40 mm diameter hole exposing the detector. In scattering experiments, for a gamma ray flux impinging on a target, there is significant probability for Rayleigh scattering to occur in addition to well-known Compton scattering.

The principle of present measurements is to observe simultaneously the intensities of Rayleigh and Compton scattered gamma rays at a particular scattering angle using a high-resolution semiconductor detector. While designing an experiment based on this technique, care must be taken to select properly the incident gamma ray energy, scattering angle and material to be probed. The intensity of coherent and incoherent peaks should be sufficient, and the two peaks must be well separated from each other, otherwise the analysis procedure becomes complicated. Because this method involves the ratio of Rayleigh to Compton peaks, the cross-section ratio depends on the Z-number of the material with which primary gamma ray flux has to interact, for a fixed geometrical source-sample-detector arrangement and incident gamma ray energy (Morgan et al., 1999).

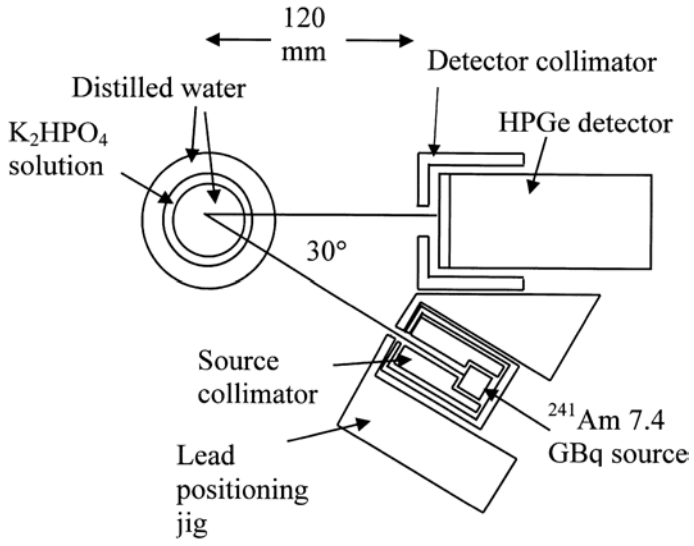

Figure 3.2: The experimental arrangement showing the ^{241}Am source, the jaw phantom and the HP Ge detector

To simulate the mandible a phantom was constructed of concentric thin-walled polypropylene cylinders as shown in Figure 3.2. The inner Diameters of the cylinders were 54 mm, 74 mm and 90 mm, creating two concentric layers of 10 mm and 8 mm thickness surrounding the inner 54 mm diameter cylinder. The outer 8 mm layer

was filled with water as a soft tissue substitute to a depth of 45 mm. Solutions of K_2HPO_4 were used as bone substitutes in the inner 10 mm layer to Simulate the mandibular bone. The inner cylinder also contained water as a soft tissue substitute.

3.6.3 Experimental Measurements

The properly shielded HPGe detector is placed at the desired angular position relative to the primary incident gamma ray beam. The spectrometer is calibrated using standard calibration gamma-ray sources of known energy. The following procedure is adopted for the present measurements.
1. The phantom-in scattered spectra are recorded for a period of 5 ks by placing each phantom, different concentrations of K_2HPO_4 (or KI solution in thin plastic vial), in the primary gamma-ray beam. The registered events originate from interactions in the phantom and background events. (Sharma et al., 2009)
2. The background is recorded for the same duration after removing the solution from the containers (or vial) to permit the registration of events due to cosmic rays and to any other process independent of the phantom.
The phantom was irradiated with the inner 10 mm layer containing varying concentrations of K_2HPO_4 to a depth of 45 mm in the range 0Âś30 g K_2HPO_4 per 100 ml water simulating bone in the density range 1000Âś1200 kg m23. In this feasibility study the irradiation time was set at 1 h as in a practical instrument many sources could be arranged around the detector in the configuration shown in Figure 3.2, reducing the irradiation time proportionately. The measurement system focus was positioned at the phantom axis rather than at the “bone” layer to increase the count rate. (Sharma et al., 2009)

3.6.4 Results and Discussion

Coherent/Compton scattering ratio

In the present study, measurements are made to study the variation of Rayleigh to Compton scattered intensity as a function of K_2HPO_4 and KI concentration in water (simulating the mandibular bone density and kinetics of thyroid iodine respectively) for 59.54 and 145 keV incident gamma rays, respectively. The scattered gamma rays are detected by a high-resolution HPGe semiconductor detector. The experiments are performed for different concentrations of K_2HPO_4 and KI in distilled water. The observed intensity ratio of Rayleigh to Compton scattered gamma flux, corrected for photo-peak efficiency of the HPGe gamma detector and absorption of photons in the target and air is determined for various concentrations. The

results of our experiments are in good agreement with that of Morgan et al. and Puumalainen et al. with regard to 59.54 keV incident gamma rays.Figure 3.3. plots the variation of the measured coherent/Compton scattering ratio. R, against the density of the K_2HPO_4 solutions. The ratios are normalized to the value for water and the error bars show the standard deviation for each measurement. The line is the least-squares fit.

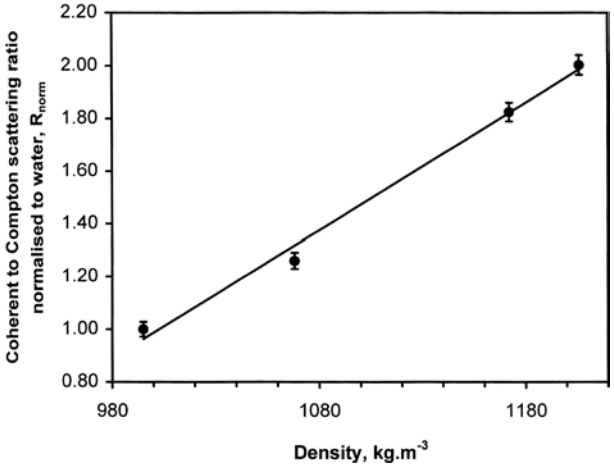

Figure 3.3: The variation in coherent/Compton scattering ratio With increasing density of the K_2HPO_4 solutions.

If S is the slope of the plot then an uncertainty of DR on the measured ratio translates to a density uncertainty (DD) of DR/S. The average uncertainty in coherent to Compton ratio over the density range 1000 $\pm$ 1200 kg m23 is 2.5-percent. The measured slope is 0.005 m3 kg21 which results in a density uncertainty of about 1-percent when derived from a ratio measurement.

Compton profile ratios

Both MacKenzie and Tartari have suggested, as an alternative to the coherent/ Compton scattering ratio, comparing the high energy tail of the Compton profile with the region dominated bysingly scattered Compton gamma-rays. These authors have suggested slightly different energy limits for these ratios. MacKenzie defined a ratio HP where the numerator is the integrated counts between 52 keV and 58 keV encompassing the high energy Compton tail, and the denominator is the integrated counts between 40 keV and 58 keV.
Tartari define a ratio Rk which results in summing over a slightly narrower portion of the high energy Compton tail. Both parameters, HP and Rk are plotted in Fig-3.4 vs density of the K_2HPO_4 solutions.

Again the ratios are normalized to that for water. A similar analysis to the above

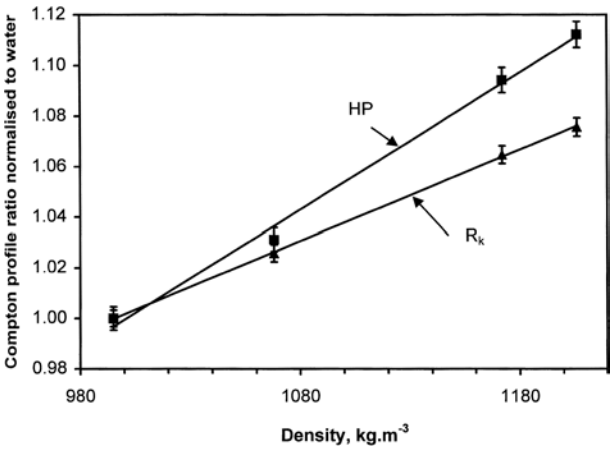

Figure 3.4: The variation of the parameters HP and Rk with increasing density of the K_2HPO_4 solutions

for the coherent/Compton scattering ratios gives an average Density uncertainty of about 1-percent when derived from either the HP or Rk ratio parameter. This is similar to the uncertainty obtained for the coherent/Compton scattering ratio. Although the slopes of the plot are much less for the Compton profile ratio measurements, the statistical uncertainty is much less because of the increased counts in the Compton tail compared with the coherent peak (Morgan et al., 1999)

3.7 How is BMD scored?; What do Z-scores and T-scores mean?

Results from a DXA are compared to two standards known as age matchedİ or young normal.İ The Z score is age-matched and the T score compares to the young normal. For children the BMD is given as a Z score. It compares to the normal range for children of the same age. Scores for adults are given as T scores. The T score compares to a healthy 25-year old person of the same sex. A T score of 0 to -1 is considered normal, a T score of -1 to -2.5 is considered osteopenic and less than -2.5 is considered osteoporotic. It is important to remember that these scores compare to adults with normal or average height. T-scores may be artificially low for adults with OI who are shorter than average.The T-score is the parameter that compares subject's BMD with average peak BMD of young normal population of the same gender.

World Health Organization Definitions Based on Bone Density Levels is shown in the following table.[24]

Table 3.2: Assessment of bone mineral density by dual energy X-ray absorptometry in osteoporosis (diagnostic categories expressed as T-scores) (Karunanithi et al., 2007)

Normal	bone density and Patient BMD is greater than 1 SD below young adult reference mean BMD (T-score > -1)
Osteopenia	Patient BMD is between 1SD and 2.5SD below young adult reference mean BMD (T-score <-1 and > -2.5)
Osteoporosis	Patient BMD is 2.5 SD or more below young adult reference mean BMD (T-score <2.5)
Severe/established/ Osteoporosis	patient BMD is 2.5 SD or more below young adult reference mean BMD with fragility fractures

CHAPTER 4
SUMMARY, CONCLUSION AND RECOMMENDATION

4.1 SUMMARY

Compton gamma -ray imaging is inherently based on the assumptions of gamma-ray scattering with free electrons. The design and understanding of advanced Compton Telescopes thus, depends critically on the ability to accurately account for Doppler broadening effects. Bone disease represents one of the most common diseases in the western world. Often the result is rarefied bone tissue, which leads to a loss in bone strength and is precursor to clinical osteoporosis.

Osteoporosis is a major health problem in the elderly population. Since accurate knowledge of the BMD and bone effective atomic number (Z_{eff}) are a great clinical value, attempts for developing accurate measurement techniques of bone quality begun several decades ago and still represent an active research area.

The measurement of the ratio of coherent to Compton scattered photons from irradiated bone gave information on the composition of that tissue. Because the ratio of coherent to Compton scatter is dependent on the atomic number of the scatterer similarly, the coherent-Compton scattering ratio of a composite material, such as bone is dependent on the atomic numbers of its component materials.
Among post-menopausal women of mean age 56 years old participated in water training program register no bone density loss, and might perhaps increase bone density by the end of study. While women that did not engage in any physical activity at all in the water training program, would manifest a decline in bone density. So exercise may be the most effective strategy to reduce osteoporotic fractures in older adults because of its potential to reduce both bone loss and fall risk.

Based on the Compton photon-scattering phenomenon, a noninvasive yet quantitative measuring method for analyzing bid was developed. Using this technique, bone density of the lower tibia was measured. Bone density was also low in all post-injury limbs.

From literatures of BMD, the objective of measurement of mandibular bone density results indicate that the intensity under the coherent and incoherent peaks observed in scattered gamma ray spectra has the potential to measure mandibular bone density and stable iodine content of tissue, respectively. A bone density test uses X-rays to measure how many grams of calcium and other bone minerals are packed into a segment of bone. A bone density test is a fairly accurate predictor of your risk of fracture.

From different literature review sources; ,some research results indicate that on patients on anti-epileptic drugs, bone loss has been mainly demonstrated; findings suggest that the diabetic osteopenia is not specific complication in calcaneousof type2-diabetic female; there is good evidience for a positive effect of oral contraceptives on BMD; Persons exposed to environmental fluoride in China are exposed to BMD loss; age related BMD, bone loss rate can be prevalence of osteoporosis; immigration between other geographical areas can affect bone mass and the lack of calcium and vaitamin-D supplements can exposed women and their newborns to BMD loss.

4.2 Conclusion

Gamma-ray scattering technique is feasible to give a measure of mandibular bone density. The Compton scattering technique may become a precise and sensitive method for the clinical diagnosis of positioning osteoporosis and quantitation of the long-term effects of limb injuries.

The quality of the bone can be estimated by the measurement of bone density by means of the Compton scattering technique. This technique assesses the integrated mass density of all the components of bone with in the measured tissue volume, including mineral, matrix and intertrabecular soft tissue. This method is based on the fact that the radiation which is scattered by the chosen part of the bone is proportional to the absolute density of the bone at this location.

Accurate diagnostic of bone disease especially in osteoporosis still needs more investigation and instrumentation development. Current bone densitometry systems measure areal density of bone. Now a days hybrid technique has been used to, in the simultaneous measurement of both areal density and mineral content of bone. From literature, we can deduced that bone mineral density measuring or bone mineral density testing of human being (particularly for aged people) using Compton scattering in different way's is one of the very important clinical tasks of developed countries given a series attention. So many Journals are written based on experiments and studies and methods of improving /increasing bone mineral density are recommended like better nutrition (milk feeding),physical exercises. etc... starting from the child hood as well as treatments are organized.

Unlike Ethiopia, where there is no any organized survey on BMD, some developed countries have voluntary foundations; Like The National Osteoporosis Foundation in USA, with the mission of preventing osteoporosis, promoting life long bone health, provides education for health professionals, patients and the public. However, all aged men and women are exposed to bone mineral density decrease, in menopausal women it is savior and are highly faced to a bone disease called, osteoporosis, a disease caused by a decrease/loss in bone mineral density.

4.3 Recommendation

These days, there are immense treatment options today than there were a few years ago. It depends on the treatment options. But more than cost considerations, the fact is that people do not take osteoporosis seriously as it is generally thought of as an old age problem particularly prevalent among women.

The best way, beside prevention and clinical treatment of the aged for less BMD, is to concentrate on children around puberty or just before and make sure they get a lot of physical activity, enough sunlight, adequate calcium and so on, so that they get better bones that would help them later in life - like a better bank balance compared to what their capacities are.

There must be organized governmental foundations and societal groups/clubs/ that can distribute educational materials on Osteoporosis. Countries should distribute lot of informative material on Osteoporosis to the members of the clubs. People must also told about the self Management of Osteoporosis by the organizations. Free Medicines should be distributed by organizations and people must be learn in becoming increasingly aware of the disease through regular campaigns.

There must be self management program for people with weak bones including workshops for teaching them various Asanas (exercises in Yoga) which will keep their Bones fit and once learnt they can regularly practice these asanas at home. Also natural therapy like Hydrotherapy, Acupuncture and Mud Therapy about how to deal with Bony Pains have to taught.

Even in Ethiopia, where there is no official movement on BMD and osteoporosis, as other people lived in the whole world, some bone loss is normal as we age. Accelerated bone loss is a concern, but so is dense, old bone that may be quite brittle. The key to strong bones is to support a healthy, balanced bone metabolism and increase the support that helps build new bone. So great emphasis must be given for this major bone health problem.

Finally, it is strongly recommended to Optimize our nutrition, a calcium supplement is not enough; Alkalize our diet some foods create acid in the body which must

be buffered by the alkalizing compounds contained in bone. Avoid meat, sugar and coffee (they are acid-forming) and eat more vegetables, fruit and nuts (they alkalize); Focus on fitness weight-bearing exercise is the most helpful for our bones; Stress, worry, and anxiety produce high levels of cortisol, which is destructive to bone, reducing stress levels through cognitive therapy or other methods can only benefit our bone health, and Consider other bone health tests to get a more rounded perspective of our bone health.. .

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DECLARATION

I the under signed declare that the project is my original work, has not been presented for a degree in any other university and that all sources of material used for the thesis have been duly acknowledged.

Name: _____

Signature: _____

This project has been submitted for examination with my approval as university advisor.

Name: _____

Signature: _____