CALCULATION OF AVERAGE GLANDULAR DOSES IN PATIENTS UNDERGOING MAMMOGRAPHY

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ABSTRACT

CALCULATION OF AVERAGE GLANDULAR DOSES IN PATIENTS UNDERGOING MAMMOGRAPHY

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The mean absorbed radiation dosage by the breast glandular tissue in mammography is called the "Average Glandular Dose" (AGD). The latest ICRP (International Comission on Radiological Protection) publication on the use of DRLs (Diagnostic Reference Level) in medical imaging recommends the AGD as DRL values. Diagnostic mammogram data about doses were collected for 253 healthy women between 40 to 64 years of ages with 1012 screenings completed in one calendar year in a medical institution in Turkey. Local DRL values for a standard two-projection mammogram with CC (Cranioncaudal) and MLO (Mediolateral oblique) projections are determined for different breast thickness as it is established and recommended by ICRP 135. AGD values were obtained by multiplying the in-air exposure on the entrance surface by the absorbed dose conversion factor using the coefficients found by Monte Carlo simulations with three different methods. Robson AGD, 2ABD and the Wu-Boone radiation dose calculation parametric methods were applied for each patient data. Excel was used to calculate the AGDs by using tube voltage (kV), half- value thickness (HVL), compressed breast thickness (CBT) and breast composition. For some breast thicknesses, the quartile values of AGDs were computed. Utilization of these results in the calculation of the first local DRLs of Turkey and therefore, we compared them with national

DRLs for each 10-mm CBT in mammography. Nonparametric statistical methods are used to determine the significance with respect to two other methods, age and CBT differences. As a result, 2ABD values were significantly higher than Robson AGD and Wu-Boone, whereas Robson AGD yielded significantly higher values than Wu-Boone. Moreover, radiation dose comparison of Robson AGD (mGy) (75th) between local and national values for the age ranges 40-49 and 50-64 shows that the local values are higher than the national values.

Keywords: Mammography, Radiation Dose Calculation Methods, Average Glandular Dose, Local Diagnostic Reference Level.

ÖZ

MAMOGRAFİ UYGULANAN HASTALARDA ORTALAMA GLANDULAR DOZ HESAPLAMALARI

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Ortalama Glandular Doz mamografi uygulamasında meme glandular dokularının absorbe ettiği iyonlaştırıcı radyasyon dozudur. Uluslararası Radyasyon Korunma Kurumu (ICRP) tıbbi görüntülemede, Diagnostik Referans Seviyeleri (DRL) birimi olarak Ortalama Glandular Doz (AGD) kullanımını önermektedir. Bir üniversitenin mamografi ünitesinde, bir takvim yılı içinde gerçekleştirilmiş bulunan 40-64 yaşlar arasındaki 253 sağlıklı kişinin 1012 projeksiyonu değerlendirilmiştir.

ICRP135 belgesinde önerilen Standart Kraniokaudal (CC) ve Mediolateral oblik (MLO) projeksiyonlar farklı sıkıştırılmış Meme Kalınlıkları (CBT) bağlamında gruplandırılmıştır. AGD değerleri, ekspojur (exposure) parametrelerinden hareketle, Monte Carlo simulasyonu ile üretilmiş katsayılar kullanılarak Robson AGD, 2ABD ve Wu- Boone radyasyon doz formülleri Excel programı kullanılarak hesaplanmıştır. Median ve Üçüncü çeyrek değerleri, X-ışını tüp voltajı, yarı değer kalınlığı (Half values thickness) 20-99 mm Sıkıştırılmış Meme Kalınlıkları ve meme dokuları bileşenleri arasında karşılaştırıldı. Bu çalışma Türkiye'de, ülke genelinde belirlenmiş her 10-mm CBT için mamografi DRL dozları ile lokal dozların karşılaştırıldığı bilinen ilk örnektir. Parametrik olmayan istatistik metodları kullanılarak yapılan

karşılaştırmalar, metodlar, CBT kalınlıkları ve yaş aralıkları arasında fark olup olmadığını araştırmaktadır. Sonuç olarak, 2ABD değerleri Robson AGD ve Wu-Boone ile hesaplanan değerlerden belirgin bir şekilde daha yüksektir. Nümerik değerler azalan sırayla Robson AGD, 2ABD ve Wu-Boone olarak bulunmuştur. Buna ilaveten Robson AGD yöntemi bağlamında lokal tanısal referans değerleri (LDRL) Ulusal değerlere göre yüksektir.

Anahtar Kelimeler: Mamografi, Radyasyon Doz Hesaplama Metotları, Ortalama Glandular Doz, Diagnostik Doz Referans Seviyeleri

Dedication

To my father Orhan Ege M.D., my mother Suzan Ege and to everyone who contributed to my education.

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TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

AEC : Automatic exposure control

AGD : Average glandular dose

CBT : Compressed breast thickness

CC : Craniocaudal projection

DRL: Diagnostic reference level

ESAK : Entrance surface Air Kerma

ESD : Entrance surface dose

FID : Focus image distance

Fr : Backscatter factor

FSD : Focus skin distance

HVL : Half value layer

kV: Applied examination voltage

kVp: Applied examination peak voltage

LDRL : Local diagnostic reference level

MLO : Mediolateral projection

NDRL : National diagnostic reference level

R : Tube output

OVERVIEW

This study contains four chapters in total. The first chapter is dedicated to clear up the definition, statistics, and importance of early diagnosis of the diseases using mammography examinations. Moreover, the techniques and tools, and some basic concepts about dosimetric measurement are presented. The second chapter contains information on mammography, definition, historical evolution, benefits and limitations. The mammographic device and dose calculation methods are also introduced in this part. Chapter 3 is devoted to exhibit the empirical results and analysis data in the form of graphical representations and tables according to age and compressed breast thickness (CBT) values. The discussion of the study is introduced in the last chapter, and concluding comments and general evaluation for this investigation can be found in the last part.

This study is based on the retrospective evaluation of routine data that should be recorded for each mammography investigation and this is provided from official medical records. Moreover, any patient-related identification was not used. Therefore, any particular patient consent and ethical committee approval are not required.

This thesis is novel in terms of its contribution to literature in the following aspects:

a) The comparison of radiological doses amounts with respect to three different calculation methods. In detecting the breast cancer yet taking into account the contributing effects of breast structure,

b) The comparison of local dose values with national dose as the first known example for Turkey based on a real life data set.

CHAPTER 1

INTRODUCTION

Mammography is world widely used as a breast cancer screening tool. Low ionizing radiation is the key component of this examination. The radiation dose received during this procedure is the main concern in terms of the potential harms to the subject. 'Biomedical Engineering' as emerging from medicine, physical science, and mathematics is essentially interrelated with such problems. Direct measurement of the radiation received by breast glandular tissue is impossible by using available techniques. For this reason, several calculation methods were introduced to guess the dose starting from exposure parameters and previous experimental results. There is no dose limit for medical exposure of patients if it is justified and optimized by relevant procedures. According to the recommendations of the International Commission on Radiological Protection (ICRP), International Atomic Energy Agency (IAEA) regulations, and also national regulation of radiation safety regulation published by the Turkish Atomic Energy Authority, all applications involving radiation must be justified.

IRCP advises each member state to generate national DRL values thereafter each center should periodically (each 6 to 12 months) revise its dose as LDRL and realize necessary readjustments. To our best knowledge, this study is to be the first example for a Local DRL calculation and comparison to National DRL values that are recently published [1]. Thus, in some way accomplishment of the study of the national values is not yet approved and recommended by the Turkish national authority of radiation protection (TENMAK). With the completion of both national and local DRL values, the national authority will have more concrete data about all hierarchical levels of the mammographic screening survey in this country and will take decisive action to fulfill the IRCP requirements. The practical result will be an example of a well-functioning radiation protection in this field.

In this thesis, the AGDs of the patients screened in the mammography unit of the affiliated hospital of Ufuk University medical school were calculated and compared with the DRL values according to the compressed breast thicknesses. One-year- period data obtained in 2020-2021, were evaluated using three radiation dose calculation methods to compare these methods with each other and also compare those values with national radiation dose levels published by a Turkish nationwide study which is expected to be approved and recommended by the national radiation safety regulatory authority.

The motivation and aim of the study are as follows:

i) To have a clear idea about the comparative evaluation of three different dose calculation methods

ii) To calculate and overview the first one-year profile of the radiation doses in a local mammography screening center to strengthen and complete the published nationwide study which aims the national standards declaration by the national authority.

1.1 Overview

This chapter provides a basic definition of cancer in general and breast cancer in particular. It discusses the importance of early breast cancer diagnosis, just as in all other types of cancer, the definitions of dosimetric entities, and definitions of some basic terms necessary for better understanding techniques and tools used in screening examinations and calculations following the data acquisition. Apart from that, it is related to the problem description and it defines the objectives that must be accomplished to satisfy the requirements of the study.

1.2 Breast Cancer

When malignant growth develops in the breast, it is referred to be as breast cancer. Cancer is a disease caused by an uncontrolled proliferation of abnormal

cells in the body. While the majority of breast cancers originate in the ducts that transport milk to the nipple (ductal cancers), some begin in the glands that produce breast milk (lobular cancers). Other forms of breast cancer, such as phyllodes tumor and angiosarcoma, are less frequent. It develops in the lining cells (epithelium) of the glandular tissues' ducts (85%) or lobules (15%). Malignant tumors begin in the duct or lobule (in situ), where they often do not produce symptoms and have a low likelihood of spreading (metastasis) [2]. Epidemiologic reports published in different parts of the world over the past 25 years showed a significant increase in breast cancer mortality [3].

1.3 Breast Cancer Statistics

In 2020, 2.3 million breast cancer cases were diagnosed, and there were 685,000 deaths worldwide. By the end of 2020, there had been 7.8 million living women diagnosed with breast cancer in the last 5 years, making it the most prevalent cancer worldwide. Women suffer from breast cancer globally more from lost years of disability-adjusted life (DALYs) than any other type of cancer. Women of all ages after puberty are experiencing breast cancer, with increasing rates of late-life in every country of the world [4]. Besides, studies have shown that, in Turkey, breast cancer outnumbers all other cancer types [5].

1.4 Diagnosis and Tools

Early diagnosis and cutting-edge cancer treatment may help reduce breast cancer deaths. Early-stage breast cancer that has not spread is relatively more treatable, therefore screening for the detection of early cancer is crucial for low mortality rates. The American Cancer Society makes screening recommendations for women who are at moderate or high risk of breast cancer. According to their guideline, women between the ages of 40 and 44 should begin annual mammography screening. Women aged 45 to 54 years old should get mammograms annually; 55 and older should either choose for biannual mammograms or continue with yearly mammograms. Screening should

continue for as long as a woman is healthy and expects to live at least another ten years. Additionally, all women should be aware of what to anticipate while having a mammogram for breast cancer screening specifically, what the test can and cannot accomplish [6].

1.4.1 Techniques and Tools of Diagnosis

Numerous tests are available to detect and diagnose breast cancer. If a suspicious region is discovered on a screening test or if symptoms develop, this may indicate breast cancer, and further testing is required to get the definitive opinion. Mammograms, Breast Ultrasound, Breast MRI, or newer and experimental Breast Imaging Tests such as Molecular Breast Imaging (MBI), also known as Scintimammography or Breast-Specific Gamma Imaging (BSGI), Positron Emission Mammography (PEM), Contrast-Enhanced Mammography (CEM), Electrical Impedance Imaging (EIT), and Elastography are the most frequently used tests.

A mammogram is the most effective technique of detecting breast cancer early when compared with the other screening programmes [7]. When mammograms, or other imaging tests, or a physical exam show a breast change that may be related to cancer, a biopsy is performed. A biopsy is the only method to determine whether or not there is cancerous tissue.

1.4.2 Importance of Dosimetry

All radiography procedures need to reduce the radiation dose as reasonably practicable in having convenient image quality. Average Glandular Dosage (AGD) is the best diagnostic method dosimetric value for the patient dose [8], which is also occasionally known as Mean Glandular Dose (MGD) [9]. Since the AGD cannot be measured directly, (as it occurs within the breast), conversion factors counting on breast size, breast composition, and x-ray spectrum have to be used for dose calculation. AGD estimates can be computed for a particular patient using the tube output, which is immediately quantifiable, and the exposure settings used to acquire the picture. The conversion factors

which are obtained by the use of Monte Carlo simulations on simplified breast models make it possible to calculate the AGD from measured Incident Air Kerma (IAK) [9]. It has been emphasized that a simplified breast model considering the composition of 50% adipose and 50% glandular tissue does not reflect reality and correction for individual glandular is necessary [10]. The tradition on this issue became a myth for practical reasons and the inconvenience due to the lack of knowledge.

1.5 Basics of Radiation and Exposure Parameters for Dosimetry

Radiation is the simple act of producing or transferring energy in the form of waves or particles across space or through a material medium, as opposed to other types of energy transfer. It is common to classify the radiation as ionizing or non-ionizing depending on the energy of the particles that are released from the source. Photon interactions come into four categories in medical physics:

i) ***Interactions of major importance*** (Photoelectric Effect, Compton scattering in the presence of a free electron, Production of pairs including triplet production),

ii) ***Moderately significant interactions*** (Rayleigh Scattering, Thomson scattering in the presence of a free-electron),

iii) ***Minor interactions*** (Reactions involving photonuclei- nuclear photoelectric effect),

iv) ***Insignificant (negligible) interactions*** (Thomson and Compton scattering by the nucleus, Production of mesons, Delbrück scattering).

Historically, at first, the term dosimetry of radiation was used in a medical sense, similar to how it is used when prescribing a dose of medication. Very soon, it became clear that physical tools for describing a dose of radiation stood out from all other biological ones.

The average glandular dose is calculated by multiplying the in-air exposure on the entry surface by the absorbed dose conversion factor. Exposure parameters of dosimetry calculations are Tube Voltage, Current (Load), Exposure Time, and Focus Distance. The tube voltage is the potential in Volts, the current (Load)

is the electrical current in Amperes, exposure time refers to the amount of time that the camera's film or digital sensor is exposed to light in seconds, the focus distance is the distance between the film and the X-ray focus in meters.

The amount of AGD is determined related to the size and composition of the breast. For the practical purpose of calculating the AGD, a breast composition of 50% glandular and 50% adipose tissue is assumed for simplicity.

It is generally recommended that systems used for mammography screening incorporate an Automatic Exposure Control (AEC). The performance of the AEC system should be tested in terms of reproducibility and accuracy under varying conditions (*e.g.*, object thickness and beam quality). The AEC system should adjust target-filter and tube voltage such that image quality is sufficient and the dose is within an acceptable range. Semi-automated systems that start from a user-defined target, filter and tube voltage, and then adapt dose according to breast transparency, are also acceptable [8].

1.6 Dosimetric Quantities

Dosimetry of radiation is now a purely physical science. The techniques for quantifying the energy deposited in a particular material by ionizing radiations, either directly or indirectly, are critical. Numerous physical quantities and units have been established characterize a beam of radiation and its dosage. This chapter discusses the most frequently used dosimetric quantities and associated units of measurement which is called ***Kerma, Cema,*** and ***Absorbed Dose***.

Kerma (*K*) is an acronym for **K**inetic **E**nergy **R**eleased per unit **MA**ss. It measures the average amount of energy transferred (*E*tr) in a small volume from indirectly to directly ionizing radiation without regard for what occurs thereafter derivative of transferred energy concerning mass:

$$K = \frac{dE_{tr}}{d_m}$$

The kerma unit is the joule per kilogram (J/kg). The gray (Gy) is the unit of

Kerma, with 1 Gy equaling 1 J/kg. Kerma is a property of ionizing radiations such as photons and neutrons.

Similar to Kerma, ***Cema*** (*CC*) stands for **C**onverted **E**nergy per unit **MA**ss. It measures the average amount of energy converted in a compact volume by directly ionizing radiations such as electrons and protons colliding with atomic electrons (*i.e.*, the derivative of converted energy with respect to mass):

$$CC = \frac{dE_c}{d_m}$$

The unit of Cema is joule per kilogram (J/kg) and the name for the unit is gray (Gy). Cema is different from Kerma in that it includes the energy emitted by incoming charged particles during electronic collisions, whereas, Kerma is a term that refers to the energy transferred to emitted charged particles.
The term "***Absorbed Dose***" refers to the amount of radiation absorbed by both indirect and direct ionizing radiation. Indirectly ionizing radiation refers to the two- step process through which energy is transferred to matter. In the first phase (which results in Kerma), indirect ionizing radiation transfers energy to secondary charged particles in the form of kinetic energy. The second phase involves the transfer of a significant portion of the kinetic energy of these charged particles to the medium finally resulting in an absorbed dose. Directly ionizing radiation occurs when charged particles release a significant portion of their kinetic energy to the medium resulting in absorbed dose.

As is the case with Kerma and Cema, the absorbed dosage is not stochastic. The absorbed dose, ***D,*** is proportional to the random amount of energy delivered ***ε,*** the energy lost by collisions along the track of the secondary particles, in the following way:

$$D = \frac{d_\varepsilon}{d_m}$$

The absorbed dosage is expressed in joules per kilogram (J/kg). The grey (Gy) is the unit of absorbed dosage [11].

Other basic terms utilized in dosimetric quantities are briefly explained below.

i) Entrance Surface Air Kerma (ESAK) is measured freely in the air at a point surface of the breast without backscatter.

ii) Compressed Breast Thickness (CBT) is the thickness after each breast is gently but firmly compressed using a clear plastic device just for a few seconds to obtain the clearest possible picture with the lowest radiation dose.

iii) Local Diagnostic Reference Level (LDRL) is the radiation dose to be used in treatment planning to ensure that doses given to patients are accurate and used to reduce these doses.

iv) Half Value Layer (HVL) refers to the thickness of a material required to produce an exit beam that is half of the intensity of the primary beam.

v) Automatic Exposure Control (AEC) maintains a constant detector signal level independent of operating mode, breast thickness, and radiographic technique.

CHAPTER 2

MAMMOGRAPHY

2.1 Overview

This chapter is dedicated to definition, history and evolution, devices, benefits and limitations of mammography and baselines of usage and formulations of the methods of dosimetric calculations. Besides, the importance and details of additional methods, like Monte Carlo simulation, and significance and effects of compressed breast thickness for the radiological examinations.

2.1.1 Synopsis

Mammography is accepted to be the gold standard technique in breast cancer diagnostic studies [12]. It is a radiological examination of the breasts and is very beneficial to use such a tool to reduce significantly the mortality rates from breast cancer. Despite its common uses, the technique is not impeccable. It does not make every cancer tissues detectable at once, especially in the case of dense breast tissues [13]. Figure 2.1 illustrates the general parts and basic properties of the device used for screenings of 253 patients whose collected data are used in this study.

Breast has two types of tissues: glandular (or fibroglandular) tissue and fatty tissue. Glandular tissues are observed as white regions on mammograms. They are milk glands and ducts of the breast. Fatty tissues, on the other hand, appears to be gray on mammograms. There beside, a breast is considered as dense if there are more glandular tissues than the fatty tissues in amount. Almost half of the women at the age of 40 and more are found to have high breast density [14].

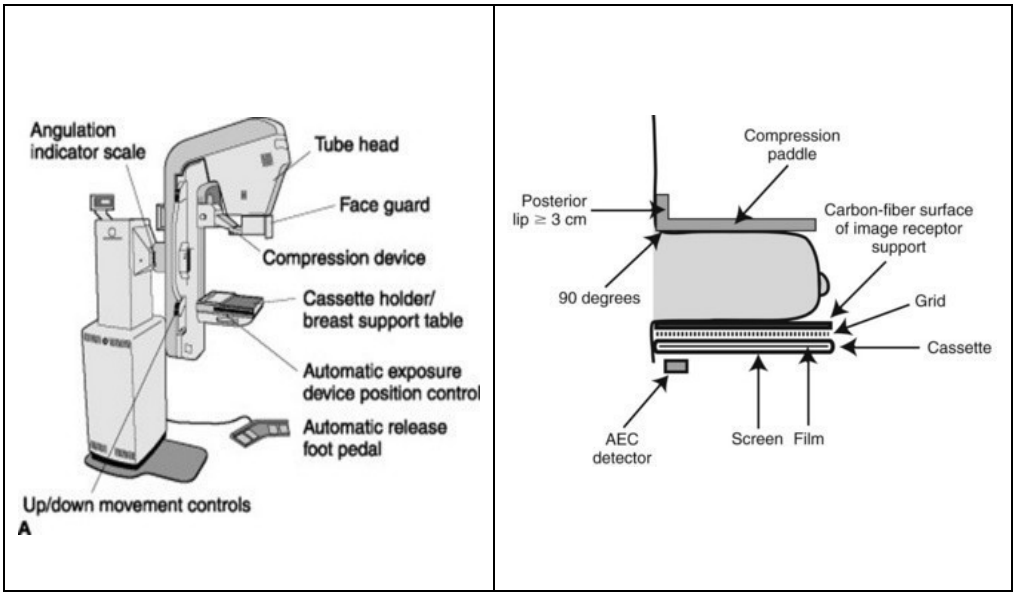


Figure 2.1. Schematic Representations of the mammography device. *https://radiologykey.com/mammography/*

2.1.2 Benefits and Limitations of Mammography

There is no upper limit on the amount of radiation to which a patient may be exposed in properly justified medical radio-diagnostic applications. However, in all X-ray exams, including mammography, the patient should receive the least amount of radiation necessary to get a picture of sufficient quality to detect suspected abnormal features. Optimisation of the exposures parameters is necessary for this purpose to keep the exposures levels lower. It is needed to compare it to other similar equipment and institutions for quality control purposes. As a result, it can be said to be critical to obtain national diagnostic reference values for medical imaging examinations that regulates radiation doses by means of the estimation and the reduction of the patient radiation doses [15]. When a group of patients has a regularly scheduled medical imaging scan, a DRL is used to evaluate if the amount of ionising radiation used in the scan is too high or excessively low. According to the Turkish radiation safety regulation authority (TENMAK, formerly TAEK) 2012 radiation safety rule, licensees are obliged to notify patients about the part of the body and effective dosage to be delivered, as well as any associated cancer risks, following medical applications [16].

Benefits of mammography are many fold**.** Mammographic screening held periodically reduces the rate of mortality due to breast cancer by up to 30%. It also reduces the risk of getting to undergo chemotheraphy since it often allows the early detection of breast cancer. Besides, mammography enables women to get information on the health of their breasts. If mammograms and other tests show no tumors, the overwhelming majority of women will not develop breast cancer [3,4]. A meta-analysis of all randomized clinical trials conducted to date on the effectiveness of screening mammography showed a substantial 20–35% decrease in breast cancer mortality in women aged 50–69 years in Sweden [17].

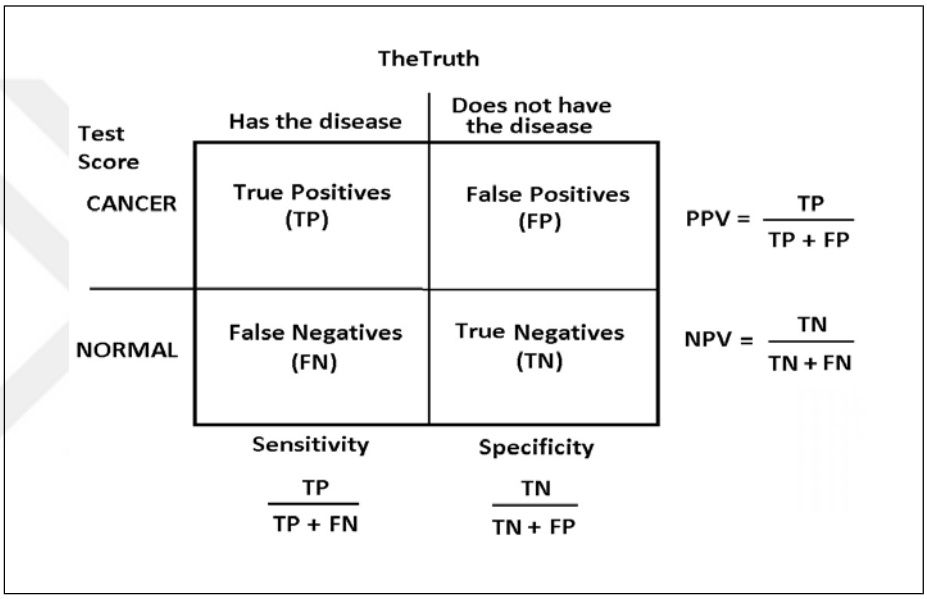


Figure 2.2. Illustration of Sensitivity, Specificity, PPV and NPV.

Studies on illustrating the accuracy of mammography refers to the True Positive (TP) and True Negative (TN) rates in the concern of sensitivity, specificity, Positive Predictive Value (PPV) and Negative Predictive Value (NPV). To exemplify, the data obtained in a study confirmed that digital mammography is an extremely accurate tool for detecting breast cancer, with a sensitivity of 97 percent, a specificity of 64.5%, a positive predictive value of 89%, a negative predictive value of 90.9%, and a diagnostic accuracy of 89.3%. Digital mammography has a few benefits over traditional film-screen mammography and is rapidly displacing the older method worldwide. However, particular care

should be used while choosing equipment, since there is a scarcity of reference data [18]. Figure 2.2 illustrate show sensitivity and specificity are found using true positive, true negative, false positive and false negative case numbers.

In terms of weakness and possible harms of mammography, when the breast cancer screening begins after the age of 40 years, the advantages of mammography exceed the radiation risk which is secondary evoked cancer [19]. Any planned activity that may expose people to radiation must provide a significant benefit to them by outweighing the hazards associated with the radiation exposure. This is known as the justification rule. The as low as reasonably achievable (ALARA) principle, in this assertion, is especially valuable when it comes to breast cancer screening. Comparing diagnostic performance across several modalities is difficult. In this aspect, two scientific issues must be resolved: (i) What constitutes a clinically meaningful performance test for a particular modality? and (ii) How to compare modalities? [20]. Breast cancer screening which lasts for many years may result in times of waiting and worry especially when further tests like MRI or breast tissue biopsy would be necessary. Nearly half of women who have been screened for years have at least one further test. Furthermore, it may result in potential overdiagnosis.

For a standard breast which is defined as 4.2 cm thick when compressed, with a 50:50 ratio of glandular tissue to fat, the AGD is typically 2 mGy per view [8]. Breast imaging studies including the use of ionizing radiation can be used to compare radiation doses and lifetime attributable risks (LARs) of radiation-induced cancer incidence and mortality. For women aged 40 years, a single PEM study with a labeled dose of 370 MBq (10 mCi) of fluorine 18 fluorodeoxyglucose is predicted to have a LAR of deadly cancer 23 times greater than that of digital mammography [21]. Figure 2.3 shows the relation between the lifetime attributable risk (LAR) and lifetime baseline risk (LBR) for female breast cancer incidence and at a reference lifetime organ/tissue dosage of 20 mGys. Both values are provided for women and males exposed at ages 1, 5, 10, 20, 40, and 60 [22]. The risk of contracting fatal cancer after being exposed to a glandular dose of 2 mGy in a woman aged between 50 and 65 is approximately 1 in 50,000 (0.002%) [8].

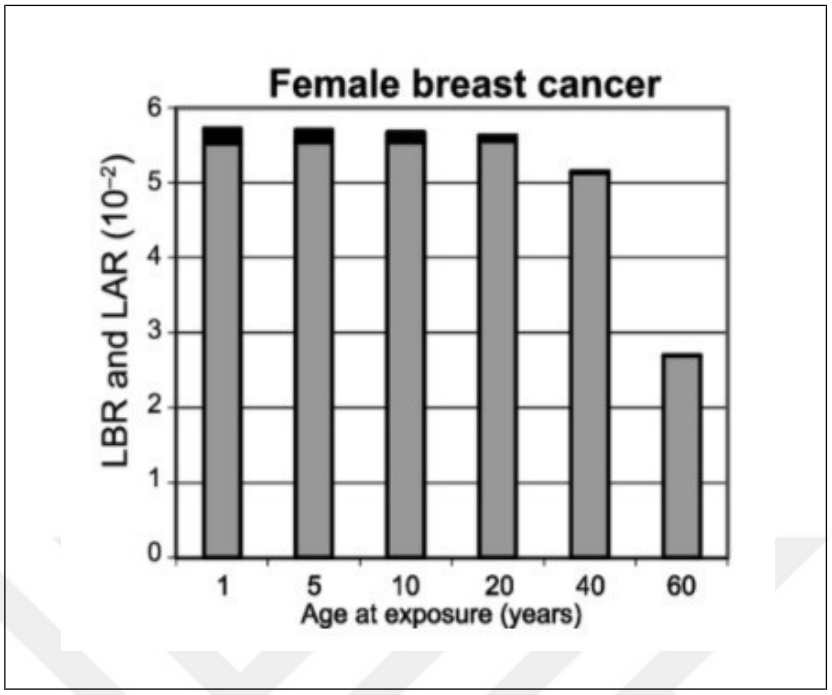


Figure 2.3. LAR and LBR graphs for female breast cancer [22].

2.1.3 Diagnostic Reference Levels

According to ICRP standards, IAEA regulations, and the Turkish Energy Nuclear and Mine Exploration Authority's (TENMAK, formerly TAEK) national radiation safety policy. All radiation applications must be justified, exposures should be optimized and the Diagnostic Reference Levels (DRLs) established by worldwide standards should be used in medical imaging. In 2020, Energy, Nuclear and Mine Exploration Authority scientists published the national DRLs for mammography [1]. DRLs were established using data from national studies and the seventy-fifth percentile of the data set was taken into account in the research.

The ICRP recommended that DRL values should be used in screening programs and diagnostic examinations (In previous report 103 [8]). The radiation dosage received by patients should be thoroughly monitored and analyzed (as per the European Directive 2013/59/EUROTAM, which became effective on

December 5th, 2013, in any mammographic quality assurance program). The AGD values are recommended as DRL values in the most recent ICRP paper (report number 135 [8]) on the use of DRLs in medical imaging. Every country needs to create DRLs in mammography, as well as other modalities using ionising radiation locally, regionally, and nationally. Local exposures are required to modify the dosage to a level that is tolerable if it exceeds a certain level defined in DRL.

DRL is not a predictor of whether a physician practice is excellent or poor medicine. It is the level advised by experts to follow the doses and keep it below. The DRL is used to determine whether the quantity of ionizing radiation utilized in a regularly scheduled imaging scan for patients in groups is too high or too low. DRL is a tool established to decrease the dose levels while producing optimal radiological image quality necessary for diagnosis.

2.2 History and Evolution of Mammography

As mentioned earlier, mammography is a radiological examination which aims the early diagnosis of breast cancer is a kind of imaging that uses a low dosage of radiation. Due to the very high radiation sensitivity of glandular tissues in breast, the absorbed radiation dose by the patient during this diagnostic processes is a very important concern of the examination. International Commission on Radiological Protection (ICRP) recommended diagnostic reference levels (DRLs) in 1996 as a means of improving X-ray examinations in general.

It should be kept in mind that, mammographic breast imaging is critical in the early detection of breast cancer starting roughly from two years before the appearance of clinical symptoms. When a radiographic abnormality occurs (*i.e.*, abnormal incidences during mammography), many radiographs are taken of it for the purpose of making a more precise diagnosis, in which the sample is collected and enlarged for easier identification [24].

Mammography, as a radiological technique that uses ionizing radiation, dates

all the way back to Wilhelm Röntgen's discovery of X-rays in 1895. Albert Salomon, a German surgeon, conducted a mammography research on 3,000 mastectomies in 1913, comparing X-rays of the breasts to the excised tissue and particularly taking notice of microcalcifications [7]. In those studies, the distinctions between malignant and non-cancerous breast tumors were found out on X-ray images. The mammograms revealed a number of details about the distribution of tumors and the boundaries, as well. Then, stereoscopic images produced by X-rays were introduced by Stafford Warren, an American physician and radiologist, in 1930. His findings of radiological examination provided images used to monitor changes in breast tissue caused by pregnancy and mastitis [25].

In 1950's breast compression technique was introduced by Uruguayan radiologist Raul Leborgne to produce better images in quality. His contribution was useful to describe the distinctions between benign and malign microcalcifications [26]. About ten years later, Robert Egan, invented the first way of screening by combining low kilovoltage peak (kVp) approachwith a high milliampare (mA) and single emulsion film. He first reported his approaches in 1959 in his paper and then in 1964 in a book titled *Mammography*. In 1970, Price and Butler achieved significant reduction in radiation levels via the use of high definition intensifying screens and mammography films. In this regard, Kodak and Dupont have made significant technological contributions. On mammography magnification in 1977, Sickles, et al., wrote on the ongoing need for improved mammography equipment, given the significance of new advancements in this field. Sickle, et al., emphasize the significance of technological capacity and ongoing improvement, as well as identifying malignant tumors via indirect and less apparent indications. Mobile mammography equipment was becoming popular at the time [27]. In September 1991, the US National Institute of Health set a priority of funding for the development of digitalmammography.

The start of the Modern Age in the development of mammography is uncertain, because, there were number of contributions. The Food and Drug Administration (FDA) established normative criteria for clinical essays in June

1996 for companies seeking FDA approval to market digital mammography equipment. A comprehensive examination of the new system demonstrates the method's technological superiority, particularly in the areas of image collecting, equalization, presentation, and post-processing [27]. Currently, many firms are developing and commercializing digital mammography equipment, computer-aided diagnostic (CAD) systems, and breast tomosynthesis.

2.3 System and Accessories of Mammography

Mammography is one of the most demanding diagnostic imaging methods, needing both high spatial resolution to detect microscopic calcifications and high contrast sensitivity to identify small malignancies. The latitude of the image-recording device must be sufficient to accurately capture information over a broad range of intensities, including areas of the breast near the skin with minimal attenuation and dense, thicker regions near the chest wall. Finally, since the breast is one of the most radiosensitive areas of the body, the examination must be performed at the lowest dose possible while maintaining the necessary picture quality [28]. This is universally known as ALARA principle, namely as low as reasonably achievable.

2.3.1 X-Ray Tube Anode

The X-ray tube's anode (or anticathode) is the part of the device that produces the X- rays. It is a usually disk-shaped piece of metal, with a diameter of about 55 to 100 millimeters and a thickness of approximately 7 millimeters, that is connected to the positive pole of the electrical circuit. Electrons moves toward the anode, where they produce X-rays while also releasing the energy. The anode disc spins and is exposed to a concentrated stream of electrons coming from the cathode, which is accelerated towards the cathode due to the high potential difference. When the electron beam strikes the anode (the real focal point), the electrons interact with the target material, generating the X-ray beam The anode angle is the angle between the vertical and the target surface, with the anode angle of the majority of X-ray tubes being between 12 and 15

degrees. A narrower angle produces a narrower effective focus point. The whole anode is not used in the generation of X-rays. On the relatively tiny rectangular area known as the focus point, X-rays are generated [29].

When electrons collide with a target, two distinct atomic processes produce X-rays:

(i) *Characteristic* X-ray emission (X-ray electroluminescence), in which the electron has sufficient energy to knock an orbital electron out of the target atom's inner electron shell. Following that, electrons from higher energy levels fill the vacancies, resulting in the emission of X-ray photons. (ii) Bremsstrahlung, a form of radiation emitted by electrons when they are scattered by a strong electric field near high- proton nuclei. The spectrum of these X-rays is continuous. Bremsstrahlung's frequency is restricted by the energy of incident electrons [31]. Figure 2.4a and Figure 2.4b show diagrams for characteristic and Bremsstrahlung X-ray generations, respectively. Figure 2.5 visualizes the photoenergies of Characteristic and Bremsstrahlung X-rays on a spectrum showing the relative intensities. The output of Bremsstrahlung (i.e., braking radiation) has a lower efficiency, but it rises with increasing energy. Electron energies drop to the maximum energy, which is equal to the applied kilovoltage peak, *kVp* [30].

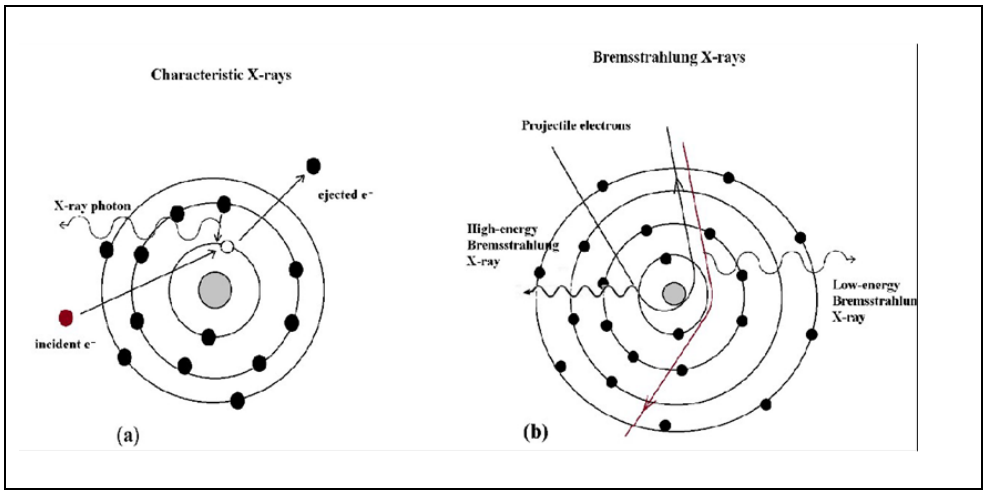


Figure 2.4 X-ray generations **(a)** Characteristic and **(b)** Bremsstrahlung [30].

2.3.2 Filters

The X-ray beam filter and its combination with anode are critical components of breast imaging systems because this choice shapes the beam spectrally for a particular target (anode), affecting picture contrast and radiation dosage. Molybdenum (Mo), rhodium (Rh), silver (Ag), and aluminum (Al) are all frequently used X-ray beam filters. The material and thickness of the X-ray beam filter used in modern mammography and digital breast tomosynthesis (DBT) systems varies [32]. The most important parameter in the selection of an anode-filter-tube voltage combination is the thickness of the breast tissue [33].

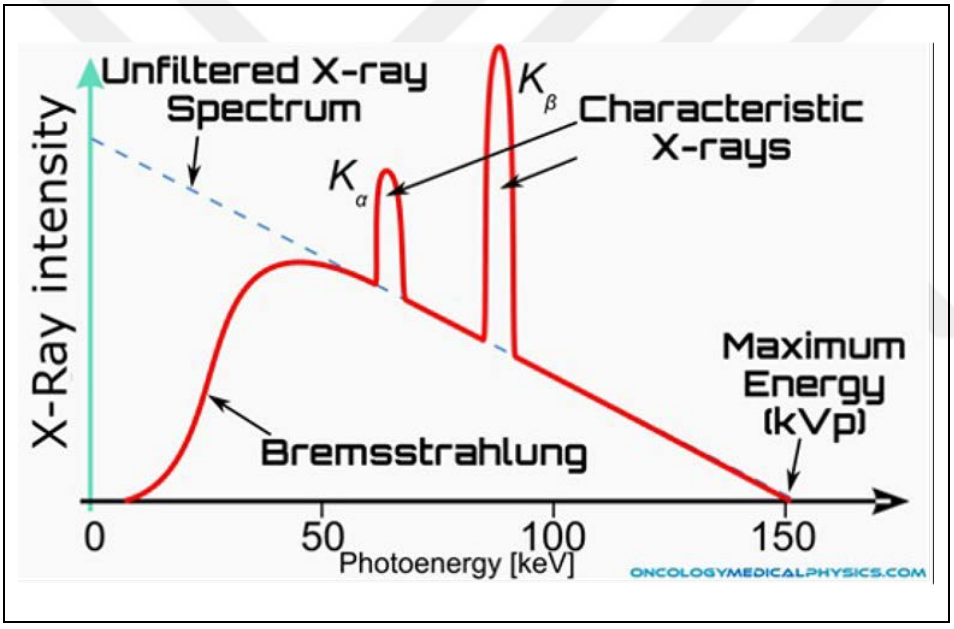


Figure 2.5. Intensity Spectrum of X-rays generations [31].

2.3.3 Voltage and Current

Kilovoltage peak, (*kVp*) is the highest voltage that may be applied across an X-ray tube. A greater value of *kVp* than the mean value is due to the fact that the voltage across the tube is not constant. Within an X-ray tube, the tube current (*mA* or *mAs*) measures how much electron flow (i.e., how many electrons per second) occurs from cathode to anode. The relationship between

tube current and electric power, P, is shown as follows:

$$P = kVp\ x\ mA$$

A milliamp current applied for a second equals one milliamp (s). Also, the energy, *E* (*i.e.*, electricity) that *mA*s is proportional to the amount of electricity is expressed as:

$$E = kVp\ x\ mAs$$

2.3.4 Regular Device Control Tests

ICRP suggests the following regular tests to be done [8]:

i) Daily Digital Tests with monitor check
ii) Weekly Digital Tests requiring homogeneity (Image quality) check
iii) Weekly Analogue Tests namely, checks of automatic exposure control and Image quality
iv) 3-6 Monthly Tests, performed by radiographer or physicist and consisting of sensitivity and radiation absorption of cassettes, film screen contact and calibration of densitometer

Quantities used for DRLs should assess the amount of ionising radiation applied to perform a medical imaging task, and should be easily measured or determined. DRL quantities assess the amount of ionising radiation used for a medical imaging procedure, not absorbed dose to a patient or organ. The one exception is mammography, for which DG may be used [8].

A 'DRL value' is a selected numerical value of an DRL quantity, set at the 75th percentile of the observations of DRL quantity distributions observed at healthcare facilities in a nation or region. DRL values are not static. As system optimisation continues, or hardware and software improve, they should be updated on a regular basis. When new imaging techniques are introduced, an effort should be made to measure appropriate DRL quantities and set DRL values as soon as it is practicable. Software tools for collection and management of dose-related data may simplify the process of establishing and

updating DRL values [8].

2.4 Compressed Breast Thickness

The anatomy of a breast is shown in Figure 2.6. The monitorization and the screening of the breast for cancer detection are also highly dependent on the breast tissue composition and breast thickness. Breast compression is offered in two different views of the breast. These views are cranio-caudal (CC) and mediolateral oblique (MLO). Figure 2.7 shows the device used in the position for both views. In the case of the uncertainty of the diagnosis, since they are in two-dimension, breast thomosynthesis can be used. Breast compression reduces distortion, motional blurs, the dose of radiation used, low image contrast due to scattering. It also provides awareness to distinguish the distinction between normal and abnormal tissues which increases results in a higher average glandular dose. Additionally, the craniocaudal views compress the breasts more than the mediolateral oblique views. Figure 2.7 contains images for both projections. This discrepancy results in an increased dosage to the patient, a little distortion, and geometric unclearity in the mediolateral oblique views [34]. For women with small and pendulous breasts, the MLO view should be taken at a 60-degree angle to make the compression better [35].

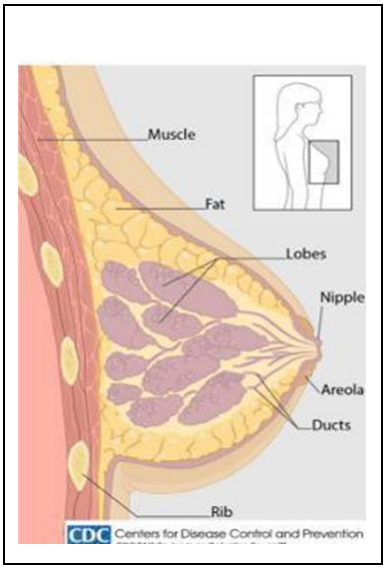


Figure 2.6. Anatomy of Breast [23]

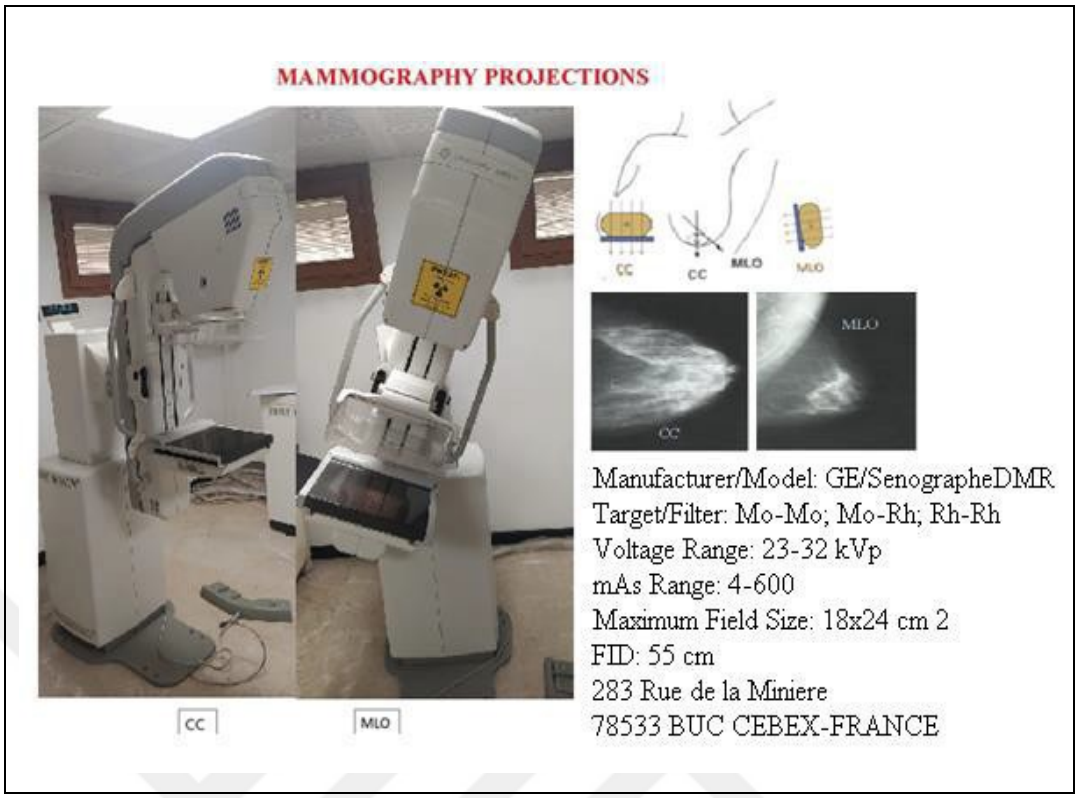


Figure 2.7. Mammography projections to obtain CC and MLO views (with the consent of Radiology Department, Ufuk University).

Adding a breast compression device as an attachment for the imaging equipment is feasible. To get the best possible pictures from a mammogram, pressure has to be applied to the breast; this may be done manually or by an instrument, and the amount of pressure given should be sufficient and within the limits of the patient's tolerance.

Breast compressing is critical for the following reasons:

i) To achieve uniform thickness and distribute the tissue in order to reveal any minor imperfection concealed by the surrounding breast tissue.

ii) To utilize the smallest dosage feasible in order to achieve the smallest possible thickness of breast tissue.

iii) To preserve the firmness of the breast in order to prevent blurring or distortion in photographs caused by movement.

iv) To eliminate dispersed radiation, resulting in a high-quality picture [36].

Technical features of the device used in the frame of this study are as follows:

i) High Frequency X-Ray Generator Delivering Constant Voltage
ii) Exposure Modes-Three Exposure Modes (Automatic Optimization of Parameters - AOP)
iii) Fully Automatic, AEC-Semi Automatic, and Manual) Offer the Ultimate flexibility and Ease of Use
iv) Magnification -Superb Magnification Images is achieved with 1.3 and 1.9 Magnification Factors and a Single Magnification Platform
v) Telescopic, Motorized Positioning Column with Command Buttons Located on Each Side and Top of the Column for Easy Access During Positioning
vi) Digital Display of Compression Pressure, Breast Thickness, Size of X-Ray Field, and Magnification Factor
vii) Motorized Compression is Controlled by Two Compression/ Decompression Foot Pedals
viii) Manual Fine Tuning Adjustment
ix) Compression Paddles-Slide Mount for Perfect Stability and Easy Mounting

For these reasons, the breast thickness is another important contributing factor to detect cancer tissues. Furthermore, other factors that affect radiation dose received by the breast include the use of anti-scatter grid and magnification mode. It is necessary to take into consideration all of the factors in the test that affect exposure, such as the tube voltage, load, exposure duration, etc.

2.5 Breast Dose Calculation Methods

Due to breast tissue's high radiation sensitivity, calculating the AGDs depends on all of the factors in the test that affect exposure, such as the tube voltage, load, exposure time, etc. As a consequence, AGD is to be the average ionizing radiation dose absorbed by (or delivered to) glandular tissue and it is a critical dosimetric parameter taken to evaluate the risk of induced carcinogenesis [37].

Despite the fact that full-field digital mammography (FFDM) equipment are being installed at an increasing rate, traditional and computed mammography systems continue to be widely used in Turkey. It is known that about 1700 of these systems which corresponds to 10% of all radiological devices used throughout the country. C- and CM-type device's AGD values of cranio-caudal and mediolateral oblique projections were examined in tissues with varied breast thickness in 275 hospitals utilizing these devices [1].

2.5.1 Materials and Methods

Taking into consideration exposure parameter values used in these tests entrance skin doses (ESDs), entry skin air kermas (ESAKs), and average glandular doses (AGD) were calculated in 1012 projections of 253 people aged from 40 to 64 years, using the related exposure parameters. In this study, the quartiles of AGDs were calculated using three different methods, according to breast thickness (CBT) between 20 mm to 99 mm measured in mammography examinations. Based on these, the first local DRLs for each 10-mm CBT measured in examinations were generated. Depending on the collection of real observations, the widely known methods in literature, Robson parametric, 2 Average Absorbed Breast Dose **(**2ABD) and Wu-Boone, are utilized in determining the optimum radiation dose. The implementation of 2ABD method on such data set is novel in literature which enables us to make also a comparison with Robson and Wu-Boone methods.

2.5.1.1 Robson Parametric Method

Having known the X-ray device's characteristic values, the incidence air Kerma and AGD may potentially be computed using the polynomial interpolation technique by means of spectral data from 25kV to 32kV values without measuring mammography tube output. AGD is the reference parameter for tissue in breasts and cannot be quantified by direct ways. However, AGDs generated in breast tissue were estimated using radiation parameters (kV, *mAs*, CBT, detection distance, filters, and factors for conversions). In other words,

AGD may be computed by ESAKs and age- related CBT factors of conversion [9, 38]:

$$AGD = K.g.c.s \quad (1)$$

Here, *K* is the ESAK value measured at the surface of the breast without any backscattering; *g* refers to the incident air Kerma for AGD conversion factor in 50% glandularity for half value layer (HVL) and breast thickness (BT); *c* is a correction factor which is considered to be 1 due to the assumption that there is no deviation from 50% glandularity composition for the breast composition; and *s* stands for a correction for deviation originating from the use of different X-ray spectrum. ESAK value can be found by using [39]:

$$ESAK = R.(\frac{1}{d})^2.q.10^{-3}, \quad (2)$$

where, *R* is X-ray tube output for a 1-meter-distance from the target (in *μGy/mAs*); and *d* is the distance between the target surface of tissue; and *q* stands for the exposure parameter in *mAs*. Here, *d* is calculated by subtraction of the thickness from the focal distance of the image. Also the tube output can be found by using [39]:

$$R = A.(kV)^n \quad (3)$$

where, *A* and *n* are the constants with values usually between one and three. The ESDs were computed in this research by the product of the ESAKs and the relevant backscattering factors, *Fr* (Altering with the Half Value Layer) as specified in EUR16263 [37]:

$$ESD = ESAK.Fr \quad (4)$$

The technique for determining absorbed dose conversion factors by including tube voltage was refined by Sobol et al. [40], HVL, CBT, and the tissue composition into the calculation, and created some program to calculate AGD values. Moreover, assorted software is created in order to enable easy estimation of mammography exposure doses without the need of a dosimeter

or measuring equipment. Since the AGD cannot be directly measured, conversion factors based on breast size, content, and X-ray spectrum needed to be established. These conversion factors, which were developed via Monte Carlo simulations on simplified breast models, enable the AGD to be calculated from the incident Air Kerma [9].

2.5.1.2 Average Absorbed Breast Dose

The 2ABD (Average Absorbed Breast Dose) technique is described as the average energy absorbed by a unit amount of breast tissue, regardless of glandularity. This is a readily quantifiable physical entity that is linked to patient exposure during mammography. The technique needs the knowledge of *kVp*, *mAs*, breast thickness T, and anode-filter combinations and given as [41]:

$$2ABD = \frac{k_{a,i}}{\mu_{en}^{d}} \left(1 - e^{d.\mu_{en}}\right) \tag{5}$$

$$k_{a,i} = \frac{Y_{tb}}{Y_0}(\alpha.kVp + \beta).mAs.\left(\frac{FID}{FID-d}\right)^2 \tag{6}$$

Here, the incident Air Kerma, $k_{a,i}$, is calculated as a function of *kVp*, *mAs*, *Ytb* and *d*. Energy absorption coefficient is $e^{-\mu_{en}}$, and the yield (*i .e.*, air Kerma to tube load ratio) is *Y* [41].

2.5.1.3 Wu-Boone Method

After Wu first introduced his method for a number of filters Boone extended this model to include more anode/filter combinations (W/Rh and W/Ag) [31, 39]. The Boone spectral model also predicts that the tube exit port has a 0.5 mm Berilyum (Be) filter, which is supported by experimental evidence. To compensate for the thicker actual Be window, the spectrum must be filtered using a thicker Be filter to make up for the difference in thickness. Each of the six filter types may be used alone or in conjunction with the others. The majority of the time, two or three will be enough [40]. Wu –Boone method refers to

$$AGD = K.D_g N \tag{7}$$

where *K* depends on *kVp*, *mAs*, anode-filter combination and *d*; *DgN* is Normalized Glandular Dose.

The primary objective of this method is to emphasize that, while the parametrization methodology produces computed results that closely match the tabular data, attempting data extrapolation could be unsuccessful. As a general knowledge it is well established that polynomial approximation considerably deviates from data based on the interpolated values. As a result, according to the proponent of this method, the parametrized procedures should not be utilized to compute normalized average glandular dosages for parameter values that fall outside the ranges specified in the original tables. By implementing a parametrization algorithm, the feasibility of employing parametrized functions to extrapolate normalized glandular dosage data for thin breasts was utilized.

The Figure 2.8 shows the interface of the Excel Office program (2019, Microsoft) used to conduct these calculations which is also done in the framework of this thesis. It can be seen that the input parameters required are given within some boundaries and choices in the menu. The choice can be Mo, Rh or W referring to the Anode type. This application enables us to determine the *DgN* and *HVL* values.

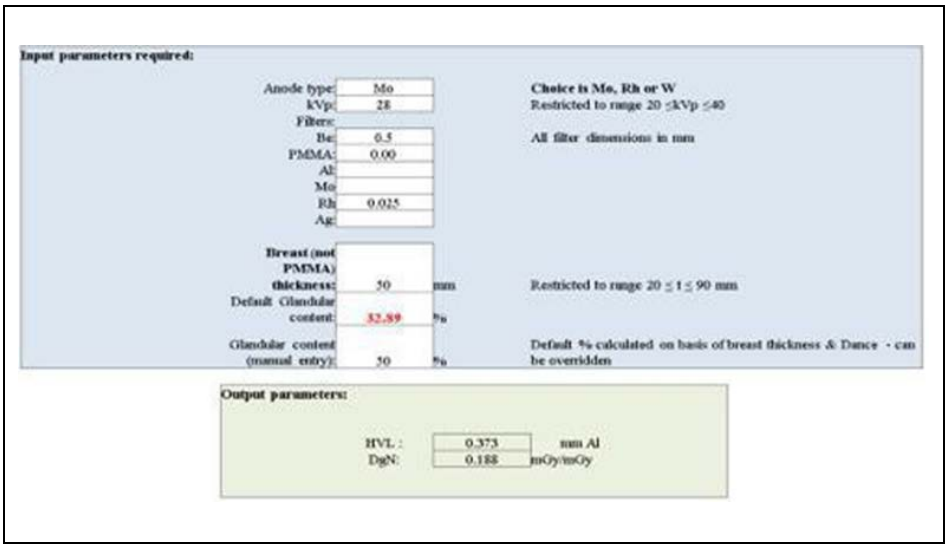


Figure 2.8. Calculation of *DgN* and *HVL* values in Wu- Boone method.

2.5.2 Monte Carlo Simulation

The Monte Carlo technique investigates events by conducting a large number of fictional experiments using randomly generated numbers produced by a computer. It is a probabilistic technique that is based on the consideration of a large number of fictive experiments with the use of random numbers. Since the number of X-ray devices in stock is large and the paucity of technician and labor, indirect calculation techniques are preferred all over the worlds in the overwhelming majority of cases instead of direct measurement of tube outputs [38]. Monte Carlo simulations may be found in a number of commercial and open-source programs; however, they may also be created. A random number generator is used to construct such a program.

In spite of the fact that mammography is generally recognized as the primary technique of breast cancer screening on a worldwide scale, there is a tiny risk of getting breast cancer as a consequence of the radiation exposure received during almost all radiological examinations. In terms of radiosensitivity, female breasts are among the most sensitive organs in the body. A greater focus should be put on the risk of radiation-induced breast cancer during mammography as a consequence of this fact. Monte Carlo simulation is a good tool to compute the conversion factors required to determine the radiation doses [40]. All three estimation techniques were used and the coefficients needed to calculate AGD values for 40-49 and 50-64 age groups were obtained via published Monte Carlo simulation of the coefficients [9] whose detailed results for the application are given in Appendix A. Tables A.1-A.3 illustrate the ‘g’ factor and ‘c’ factors for two age groups and Table A.4 presents the random AGS sample (CC and MLO) for some patients using simulations obtained based on the data set utilized in the frame of the thesis.

CHAPTER 3

EMPRICAL ANALYSES AND RESULTS

3.1 Overview

The data set collected retrospectively from patients examined in a research hospital in Ankara, Turkey. With the permission of Ufuk University Medical School, Radiology Department in Ankara-Turkey, 1012 mammographic screenings for 253 female patients screened within a year (2020-2021) constituted the data for proposed analyses. Three radiation doses, AGDs, were estimated using examination of females who underwent mammographic exams, whose ages are classified between 40 to 49 and 50 to 64 ages, using the Robson AGD, the 2 ABD, and the Wu-Boone Methods in terms of the coefficients generated following Monte Carlo simulations. The AGDs are calculated using Excel. Tube voltage (*kV*), half-value thickness (*HVL*), compressed breast thickness (*CBT*), and breast composition are considered. The 75th percentile values of AGDs were determined for each thicknesses of 20-99 mm, and the first local and national DRL value comparison for each 10-mm-CBTs inexaminations.

The data set shows that the mean age of the participants is 51.5 with a range between 40 and 64. For right and left breasts, we determine the CC and MLO projections for each patient.

3.1.1 DosimetricStudy

The study includes two hundred fifty-three (253) individuals who hadscreening and diagnostic mammography. This investigation is focused on a particular hospital data in order to calculate the local DRL values. As recommended by ICRP 135, local DRL values for a conventional two-projection mammography with CC and MLO projections are calculated for various breast thicknesses. Figure 3.1 visualizes the summary of AGD estimation using Robson AGD and

2ABD methods. The information collected and categorized in administering these methods are described with the important factors (i.e., half value layer (HVL), entrance surface air Kerma, CBT, breast tissue composition) to be taken into account.

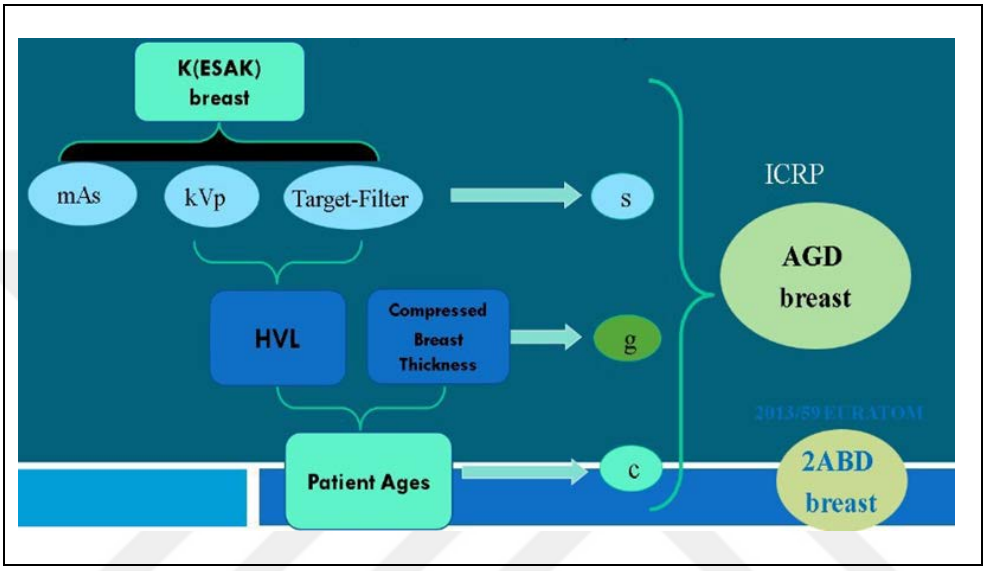


Figure 3.1. Estimation of AGD values using technical parameters.

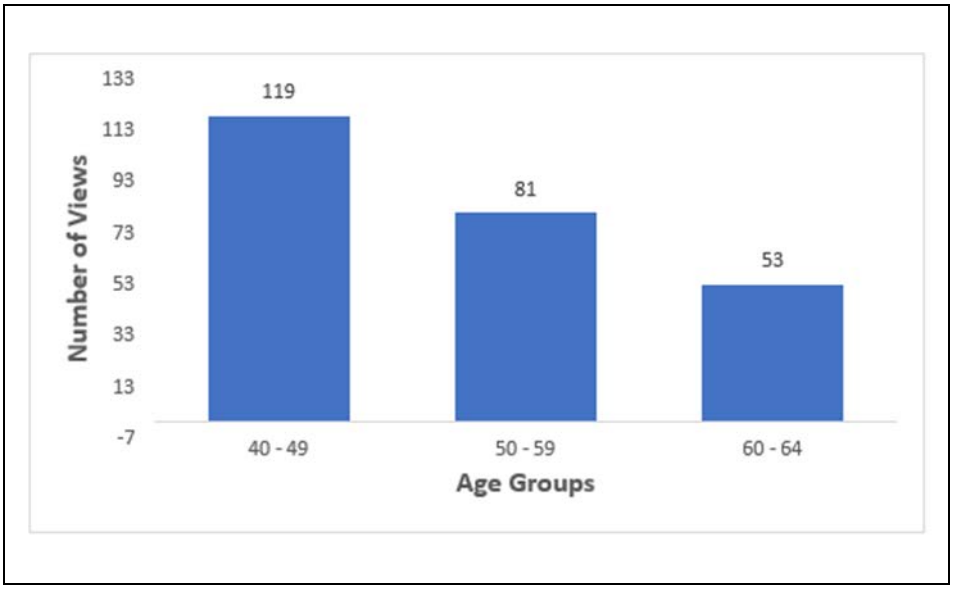


Figure 3.2. Total number of views according to age groups.

Figure 3.2 summarizes the relation between the number of views and the age groups of the participants. It shows the overall number of views between 40-49, 50-59 and 60-64 years of which are 119, 81 and 53, respectively. The majority of the patients are accumulated within the age range of 40-49, which is highly recommended age to breast cancer prevention examinations.

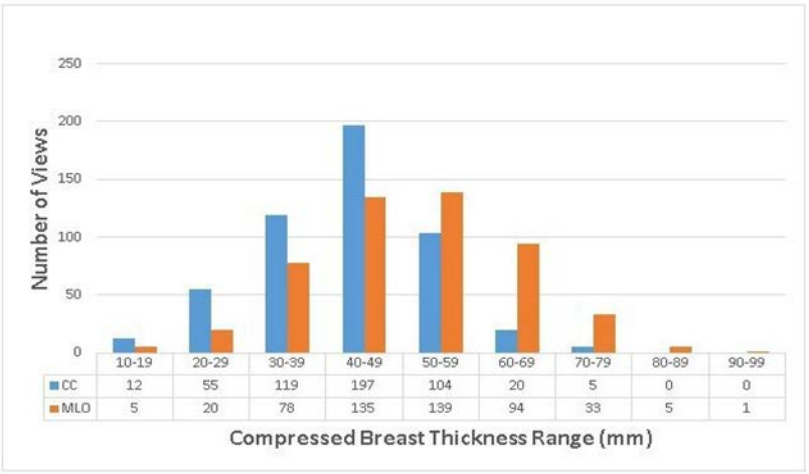
3.1.2 Compressed Breast Thickness Projections

Compressed breast thickness (CBT) plays an important role in the detection of the cancer tissue. For this reason, we analyze the CBT distribution with respect to its certain characteristics.

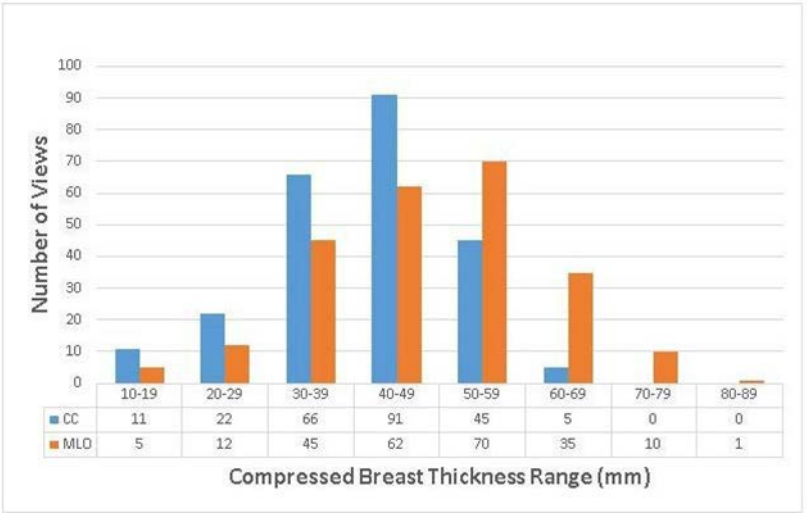
Figures 3.3a-c show the CBT values according to CC and MLO projections for all patients, for the age groups 40-49 and 50-59, respectively. Fig 3.3a depicts that the CBT of for CC view 40-49 mm is the most frequently seen thickness (197 patients). 30-39 mm (119 patients) and 50-59 mm (104 patients) are the second and the third. For MLO view the decreasing order of CBTs is 40-49 mm (135 patients) and 30-39 mm (78 patients) 50-59 mm (139 patients).

Figure 3.3b shows the distribution in 40-49 years of age group. For CC view the decreasing order of CBT is 40-49 mm (91 patients), 30-39 mm (66 patients), and 50- 59 mm (45 patients). For MLO view the decreasing order is 50-59 mm (70 patients), 40-49 mm (62 patients) and 30-39 mm (45 patients). For the older ages, 50-64 ages,

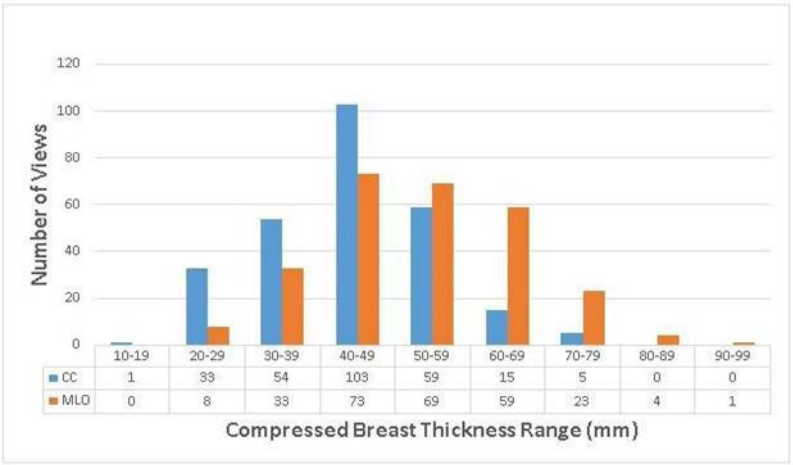
Figure 3.3c explains that the decreasing order CBT is 40-49 mm, 50-59 mm and 30-39 mm. This relation holds both for CC and MLO groups having CC the highest values of 103,59 for age group 40-49.



(a) All patients



(b) Ages 40-49

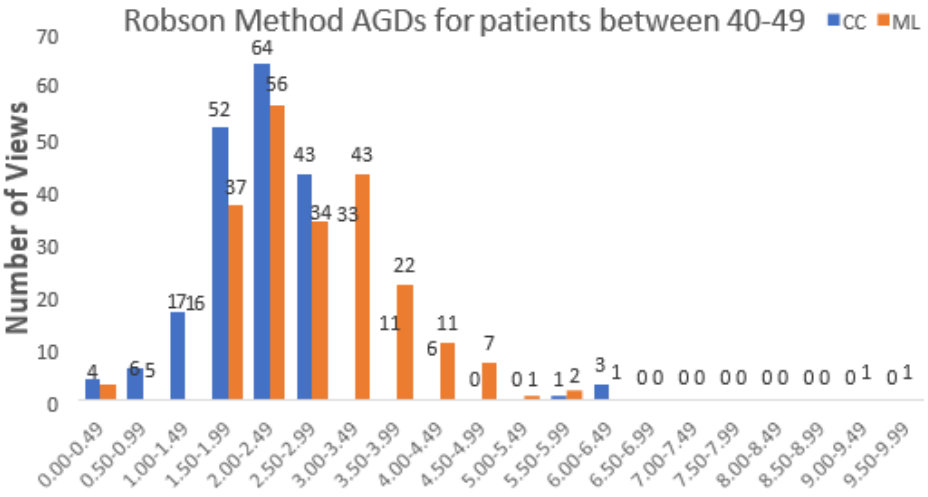


(c) Ages 50-64

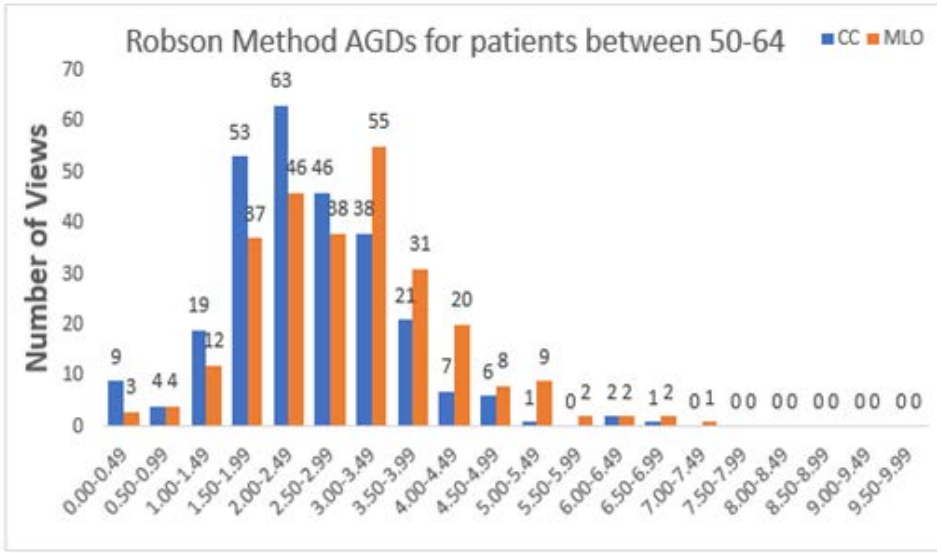
Figure 3.3. Number of views in terms of CBTs.

3.1.3 AGD Projections

AGD values calculated based on each method constitute the main base for the comparisons. Figures 3.4a-b show the number of views corresponding to AGD values obtained via Robson AGD method for age groups 40-49 and 50-64 ages.



(a)Age 40-49



(b) Age 50-64

Figure 3.4. Number of views of AGD values by Robson AGD method

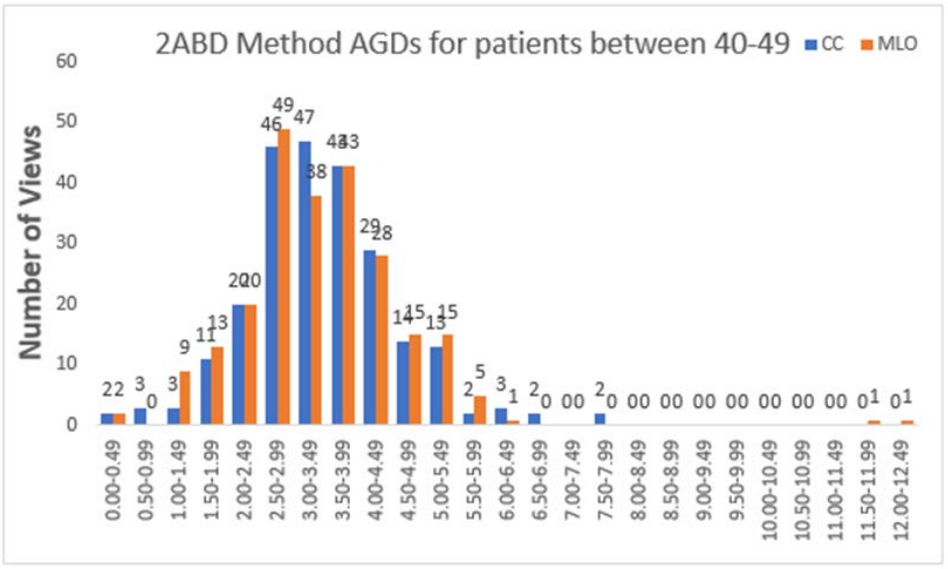
Figure 3.4a shows the distribution of the corresponding AGD values for Robson AGD method between 40-49 of ages. Doses received are mostly located between 1.50 and 2.99*mGy* whereas the same method yields dose amounts between 1.50 and 3.49 *mGy*. (Figure 3.4b) for older ages (50-64).

The dose calculations using other two methods are performed. 2ABD method gives higher dose amounts for two age groups. Figures 3.5a-b illustrate that doses are higher than Robson, but the same for both age groups and is between 2.50 and 4.49*mGy*.

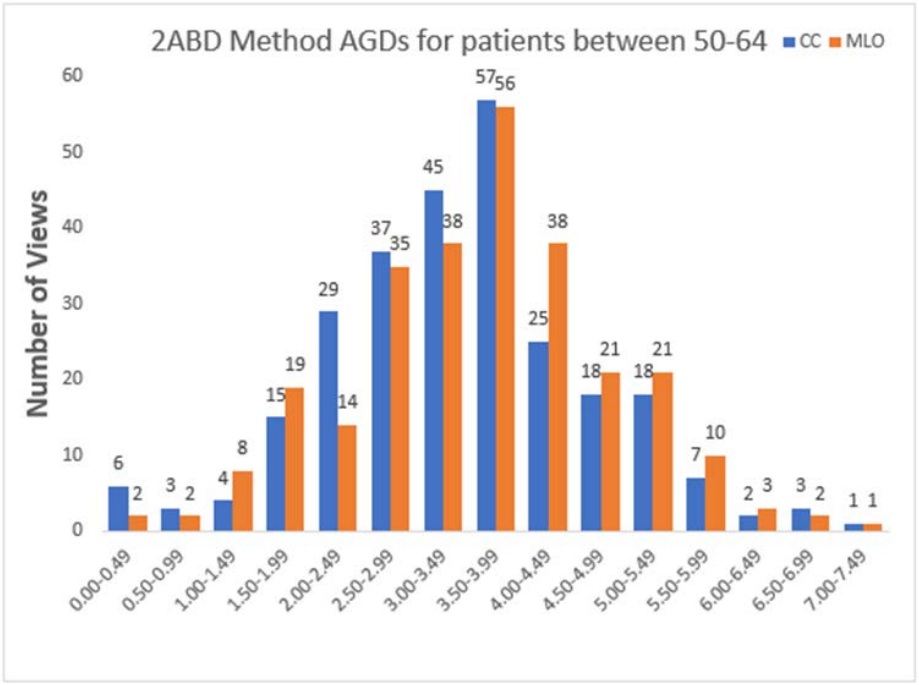
The same plots are done using Wu-Boone method. Figures 3.6a-b, respectively show the number of views corresponding to AGD values for age groups 40-49 and 50-64. The doses for both age groups are the same. Compared to the other methods, Wu-Boone yields dose values (between 1.00 and 2.99 *mGy*) similar to Robson for the age group 40-49, however remains much smaller in older ages. Additionally, the dose values remain much lower than the values obtained from 2ABD method.

It should be noted that AGD values in Robson range between 0-9.99, rarely observed over 7.00 for both age groups. On the other hand, 2ABD method experiences a wider range having the largest dose around 12.49. It is interesting to mention that, for the older ages the range follows similar pattern to Robson. Additionally, Wu-Boone also show longer tail behavior at age interval 40-49, yielding the maximum dose amount being around 9.49, but more compact distribution for age 50-64 compared to other two methods.

These distributions are the visual illustrations of why the dose calculations should be determined with respect to different methods to reduce overdose possibilities. These comparisons also alleviate the necessity to analyze multi-dimensional influence on the dose selection.

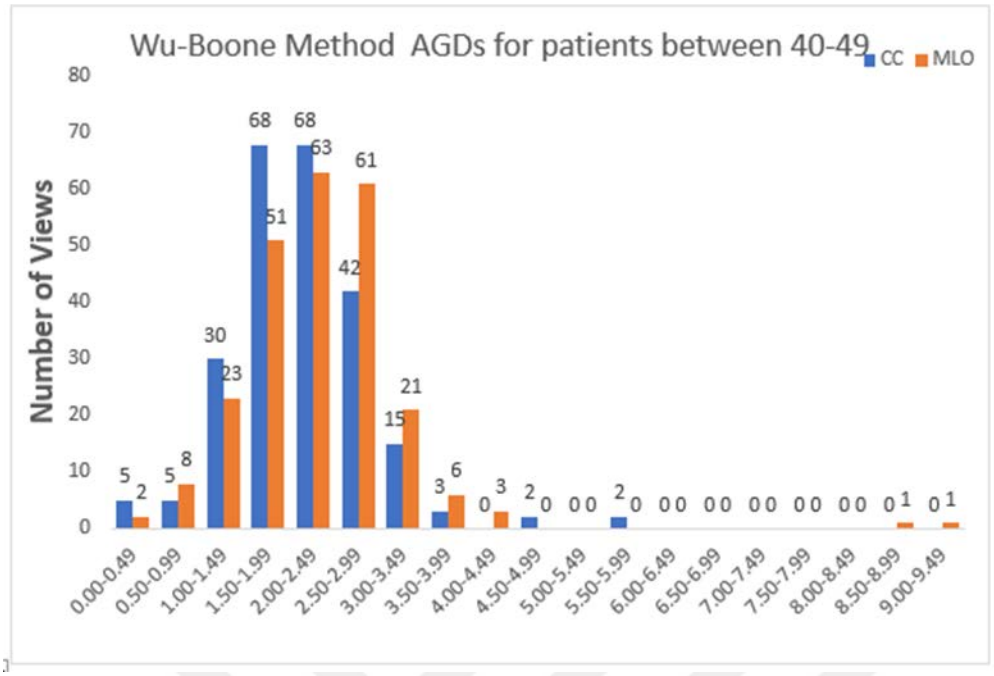


(a) Age 40-49

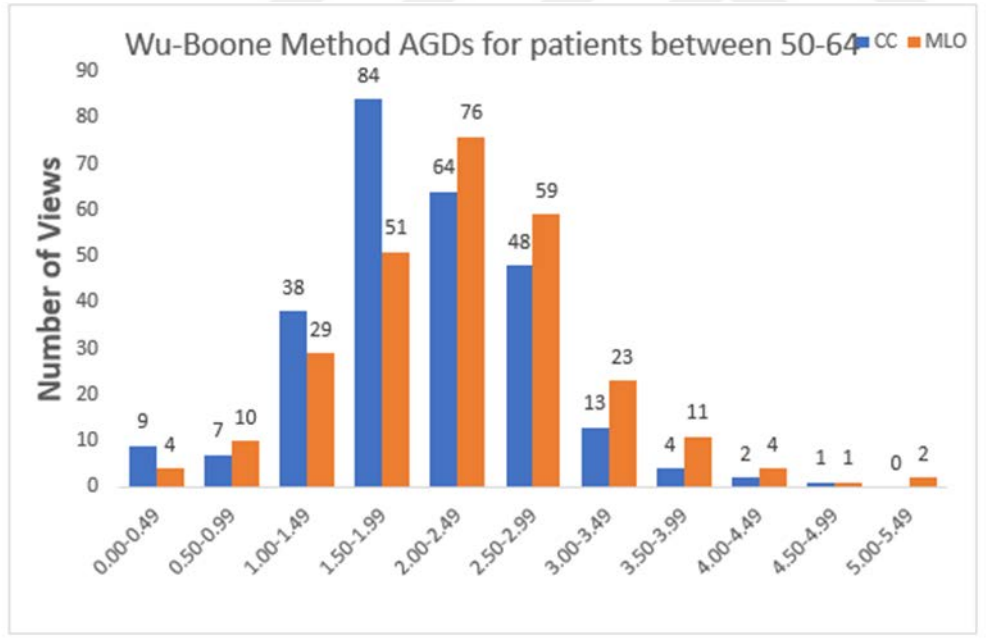


(b) Age 50-64

Figure 3.5. Number of views of AGD values by 2ABD method.



(a)Age 40-49



(b)Age 50-64

Figure 3.6. Number of views of AGD values by Wu-Boone method.

3.1.4 Statistical Analyses

3.1.4.1 Preliminaries

To determine the impact of the selected dose calculation methods, we implemented statistical analyses based on a real data set. The data set can be analyzed under parametric models which allows us to implement conventional hypothesis testing approaches. For this aim, the variables should be checked if they fulfill certain statistical conditions, such as normality which cannot always be implemented, especially, if the variables are categorical. Additionally, if the interval (numerical) data does not allocate enough number of observations, where the grouping is required, the normality assumption does not hold either. In such situations, nonparametric approaches become useful to implement comparative analyses.

As some of its features are described in earlier sections, the data set used in this thesis is composed of some categorical and numerical variables. The observations collected at Radiology Department of Faculty of Medicine at Ufuk University is a good representation of local radiation doses of mammography screenings. In comparative analyses, the findings related to the data set will be stated as "local". Among 12 variables of which are 9 numerical and 3 categorical, we have

i. Numerical variables: CBT, kVp, mAs, Robson ESAK, Robson ESD, RobsonAGD, 2ABD and Wu-Boone AGD values.

ii. Categorical variables: the method projection group, age and CBT groups.

Additionally, the observations are characterized as follows:

i) For a total number of 253 patients, 506 CC and 506 MLO projections were recorded.

ii) Statistical quantification varies based on categorical and numerical variables (Table 3.1). In the categorical variables, numbers and percentages were taken into account, whereas, numerical variables are quantified in terms of their Mean ±one standard deviations, 25^{th} percentile (**Q1**), median (**Q2**), 75^{th}

percentile (**Q3**), and 95th percentile (**P95**), while it is very commonly used important ndicators in medical researches.

For the numerical variables, the normal distribution property was performed using **Kolmogrov Smirnov** test whose p-values resulted in the favor of rejecting the null hypothesis ($p>0.05$). This leads us to switch to the nonparametric methods to perform the necessary and required comparative analyses to determine the differences among methods and other contributing factors. Guided by the nonparametric approaches, for the pairwise comparisons **Mann Whitney U** test, for multivariate comparisons **Kruskal Wallis H** test are used. These tests basically, question if there exists any difference between the medians of paired groups. To reserve more space for the analyses, the technical details of Mann Whitney U and Kruskal Wallis H tests are not covered in the content of this thesis. The decision criteria for both tests is made based on the level of 95% confidence level with the p-values less than 0.05 ($p<0.05$) to be significant. Statistical evaluation of data was carried out by means of the software SPSS 20.0.

Table 3.1. Categorical and numerical values used for statistical analyses.

Categorical Variables	Descriptive Statistics (numbers and percentages) Number of cases, mean, standard deviation, and maximum-minimum
Numerical Variables	Mean ± standard deviation, 25th, 50th (median), 75th, 95th percentiles

3.1.4.2 Empirical Findings

In the preliminary analyses of the variables, we summarize first the basic characteristics using descriptive statistics. In reference to Table 3.1., the numerical values listed in Tables 3.2 contain the minimum, maximum values, mean and standard deviation (SD) of 506 observations. AGD values on average for three methods yielded the highest in 2ABD, whereas Wu-Boone gave the

smallest standard deviation compared to other two. The percentiles for the same variables are shown in Table 3.3 which also illustrates the tail behavior on the data. It should be mentioned that the percentiles are important indicators to determine the skewness and outliers in data set.

Table 3.2. Descriptive statistics of numerical variables(*n*=506)

***n*=506**	**Minimum**	**Maximum**	**Mean**	**SD**
CBT_cm	1.50	8.90	4.6484	1.24633
CBT_mm	15.00	89.00	46.4838	12.46333
kVps	24.00	33.00	27.6570	1.54823
mAs	15.50	414.50	156.9156	74.77697
Robson_ESAK	.80	40.33	12.1486	5.69359
Robson_ESD	.85	44.57	13.2659	6.24184
Robson_AGD	.16	9.00	2.6458	1.02996
ABD	.25	12.12	3.4785	1.16185
Wu_AGD	.12	9.01	2.1786	.77062

Table 3.3. The percentiles for numerical variables (*n*=506).

	Percentiles			
***n*=506**	**Q1**	**Q2**	**Q3**	**P95**
CBT_cm	3.85	4.60	5.50	6.70
CBT_mm	38.50	46.00	55.00	67.00
kVps	26.00	28.00	29.00	30.00
mAs	102.50	134.50	207.00	295.00
Robson_ESAK	8.21	11.07	15.28	23.55
Robson_ESD	8.96	12.11	16.75	25.88
Robson_AGD	1.96	2.53	3.21	4.36
ABD	2.80	3.43	4.13	5.21
Wu_AGD	1.73	2.16	2.59	3.32

For the categorical variables the projection groups are equally likely distributed (Table 3.4), whereas, the age distribution is slightly dominated by 50-64 (Table 3.5). There are two extreme ages, 22 and 67 whose influences in the study are found to be insignificant. The breast thickness, CBT, groups are mostly dense within 39.1-59.0 as given in Table 3.6.

Table 3.4. Projection group distributions.

Projections		
	Frequency	%
CC	253	50.0
MLO	253	50.0
Total	506	100.0

Table 3.5. Age group distributions

Age Group		
	Frequency	%
40-49	119	47.0
50-64	134	53.0
Total	253	100.0

Table 3.6. CBT group distributions

CBT mm Group		
CBT	Frequency	%
15-19	6	1.2
19.1-29	35	6.9
29.1-39	98	19.4
39.1-49	165	32.6
49.1-59	128	25.3
59.1-69	52	10.3
69.1-79	19	3.8
79.1-89	3	0.6
	506	100.0

Parameters of examinations with respect to age groups were tabulated in terms of their means, ranges and SDs in Table 3.7. We observed that average CBT was higher in CC projections compared to MLO projections for both age groups, as well as, the older ages yielded higher mean CBT. Range and SD values behave similar to mean in terms of projection types and age groups.

Table3.7. Parameters of projections with respect to some statistics.

AGE		**40-49**			**50-64**		
Projection	**Mean ± SD**	**44.41 ± 2.87**			**57.76 ± 4.71**		
		CBT	**kVp**	**mAs**	**CBT**	**kVp**	**mAs**
CC	**Mean**	4.05	27.74	135.96	4.37	27.02	158.92
	SD	1.04	1.58	57.92	1.06	1.46	80.00
	Range	4.30	9.00	262.00	5.40	6.00	399.00
MLO	**Mean**	4.82	28.24	150.57	5.31	27.70	179.16
	SD	1.26	1.46	72.32	1.24	1.46	79.26
	Range	5.75	7.00	340.00	6.35	5.50	333.50

As next, we investigated the percentile behavior of doses with respect to three selected methods. Tables 3.8-3.10 summarize the AGD values for Robson, 2ABD and Wu-Boone methods, respectively. It should be noted that due to its methodology and common use Robson method has two other outcomes to be mentioned; ESAK and ESD along with AGD.

We focused on AGD values which is the main interest of this study. The projections, age groups and methods on each percentile base exposed the same behavior. MLO's were higher in 50-64 age group, being the highest in 2ABD method. On the other hand, Wu-Boone, being slightly higher, comprised with Robson for both age groups. These findings also proved the influence of the methods to be analyzed thoroughly.

Table 3.8. AGD quartiles using Robson AGD Method.

Age		ESAK (mGy)				ESD (mGy)				AGD (mGy)			
		Q1	Q2	Q3	P95	Q1	Q2	Q3	P95	Q1	Q2	Q3	P95
40-49	CC	7.73	9.92	12.62	18.45	8.43	10.78	13.81	20.00	1.86	2.33	2.82	3.63
	MLO	8.24	11.38	16.32	24.54	9.07	12.52	17.61	26.90	1.96	2.61	3.24	4.38
50-64	CC	7.56	10.34	14.56	20.76	8.30	11.26	15.70	22.52	1.86	2.37	3.04	4.28
	MLO	8.87	13.86	18.55	24.52	9.74	15.25	20.22	26.87	2.17	3.01	3.61	4.83

Table 3.9. Quartiles of AGD using 2ABD Method.

Age	Projections	2ABD (mGy)			
		Q1	Q2	Q3	P95
40-49	CC	2.82	3.39	3.88	5.06
	MLO	2.82	3.32	3.95	5.21
50-64	CC	2.72	3.37	4.24	5.24
	MLO	2.95	3.70	4.28	5.41

Table 3.10. Quartiles of AGD by Wu-Boone Method.

Age	Projections	AGD (mGy)			
		Q1	Q2	Q3	P95
40-49	CC	1.70	2.12	2.50	3.10
	MLO	1.81	2.20	2.70	3.33
50-64	CC	1.62	2.01	2.45	3.17
	MLO	1.79	2.32	2.71	3.54

The next step in the analyses, was to compare the means, medians and 75th percentiles of the methods which would also constitute a basis for the comparison to the national AGD values obtained in the guiding literature [1] as much information as possible.

Table 3.11. The summary of DRLs (Q3 of AGDs) for three methods.

	Robson AGD (mGy)				**2ABD (mGy)**				**Wu-Boone (mGy)**			
Age	**40-49**		**50-64**		**40-49**		**50-64**		**40-49**		**50-64**	
CBT	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**
15.0-19	2.08	1.46	-	-	3.89	2.78	-	-	2.07	1.51	-	-
19.1-29	1.97	2.46	1.86	2.21	3.42	4.53	2.85	3.97	1.95	2.55	1.87	2.04
29.1-39	2.51	2.32	2.26	2.40	3.74	3.30	3.42	3.54	2.29	2.12	1.99	2.05
39.1-49	2.76	2.93	3.03	2.96	3.76	3.66	4.53	3.91	2.45	2.49	2.47	2.40
49.1-59	3.44	3.21	3.57	3.57	4.66	3.65	4.45	4.45	2.80	2.58	2.63	2.71
59.1-69	-	3.99	4.56	4.06		4.61	4.87	4.17	-	3.15	3.32	3.00
69.1-79	-	4.81	6.52	5.34		5.21	6.74	5.54	-	3.51	4.52	3.74
79.1-89	-	-	-	6.60		-	-	6.46	-	-	-	4.63

(a) Analyses with respect to 75th Percentiles

In regards to the behaviors of Q3 AGD values, we elaborate the analyses by including CBT groups along with age groups and projections (CC and MLO). Table 3.11 depicts that, regardless of the type of projections, the 75th percentile of AGDs for ages 40-49 2ABD method gave the highest values, having preserved the same order for the methods at age group 50-64.

The influence of CBTs had increasing effect on AGDs, as CBT become larger. It should be noted that the missing values in Table 3.11 is related to no such combined observations to be available in the data set.

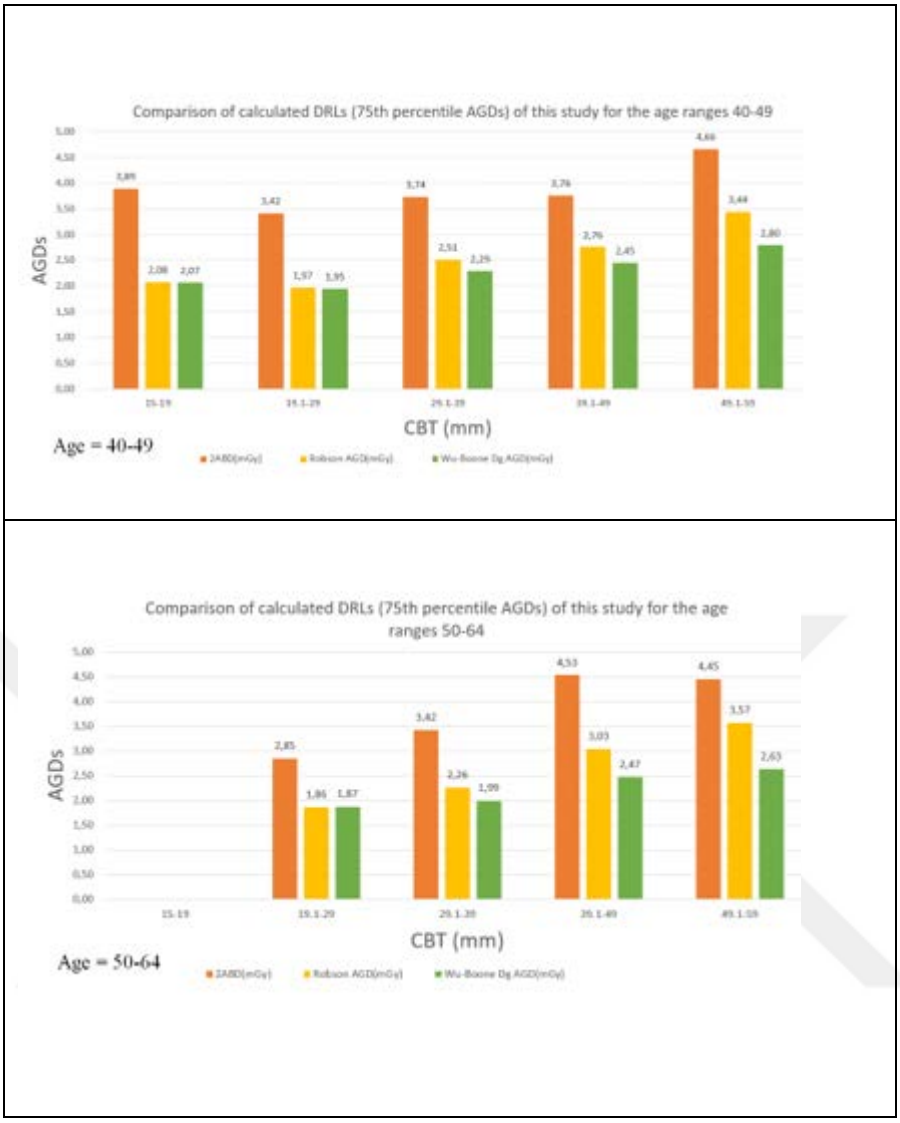


Figure 3.7. CC dose amounts with respect to CBT and age groups

The graphical illustrations are shown in Figures 3.7a-b and 3.8 a-b. Both figures also show the numerical decreasing order of three methods with the following ranks:

(i)For CC:

- Independent of age, 1ABD exceess Robson AGD and Wu-Boone for all CBT groups
- Robson AGD values are almost equal to the ones with Wu-Boone for CBT<30mm
- Robson AGD exceeds Wu-Boone values for CBT>30mm (Figure 3.7a-b)

(ii)For MLO:

- Independent of age, 2ABD exceeds Robson AGD and Wu-Boone
- Increase in CBT causes decrease in the difference between the AGD values obtained from three methods (Figure 3.8a-b).

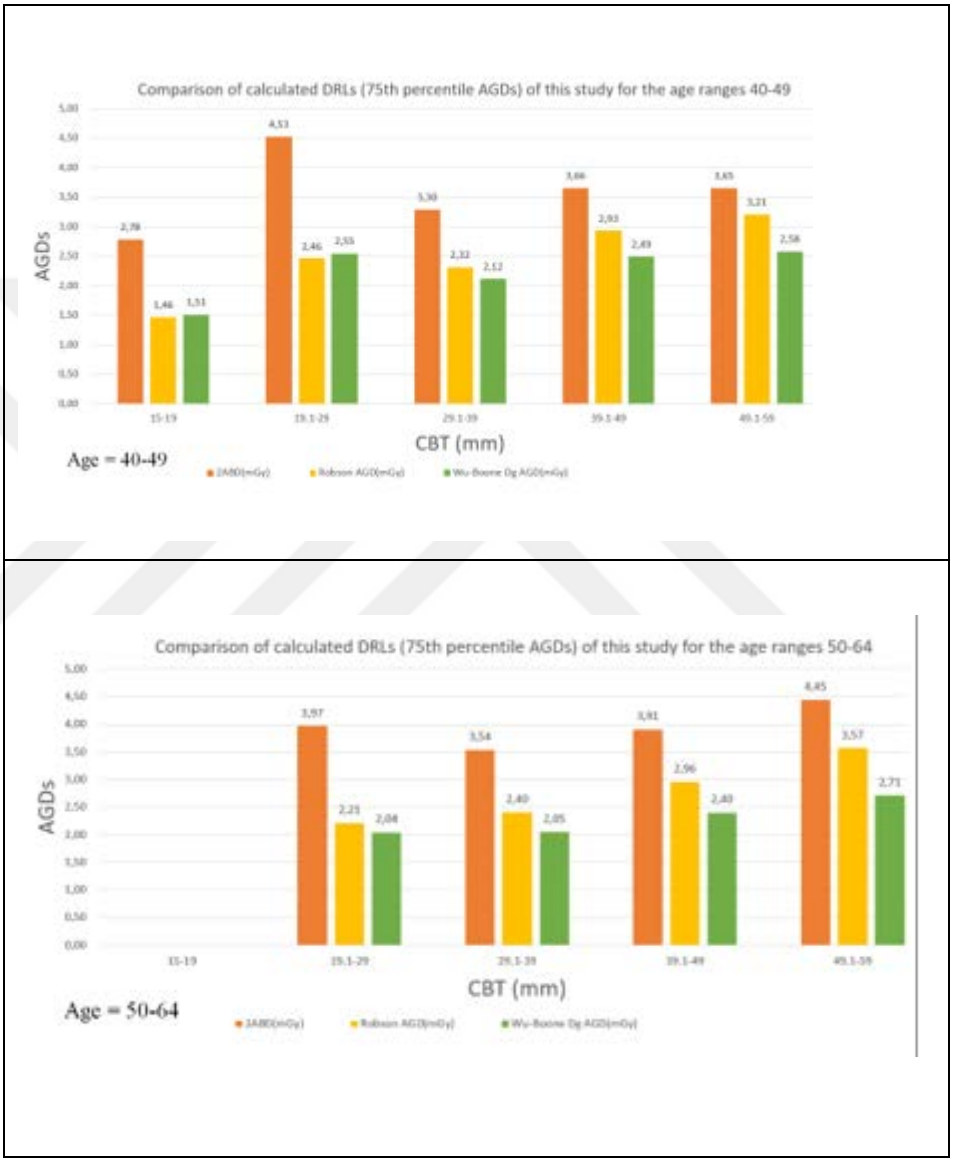


Figure 3.8. MLO dose amounts with respect to CBT and age groups

The verification of the findings with respect to the national AGD values are performed. Table 3.12 presents AGD values for both national and local (based on

the date studied in this thesis) pertaining the same classifications for age, projections and CBT groups. The difference between national and local values are taken as the indication of discrepancy in the local applications. It was shown that more than 70% of the AGD (mGy) (**Q3**) values remain below local values. It should be noted that, the comparison is restricted to Robson AGD as the national values are studied only for this method [1] .

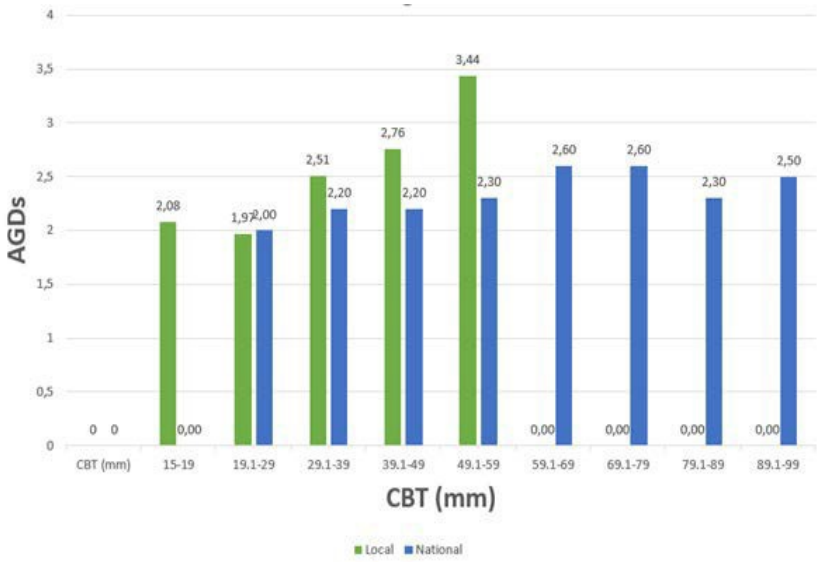
Table 3.12. Comparisons of Robson AGD (Q3) national and local values

	Local				**National**				**Difference**			
Age	**40-49**		**50-64**		**40-49**		**50-64**		**40-49**		**50-64**	
CBT	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**
15.0-19	2.08	1.46	-	-	-	-	-	-	-			
19.1-29	1.97	2.46	1.86	2.21	2.00	3.00	2.60	3.10	0.03	0.54	0.74	0.89
29.1-39	2.51	2.32	2.26	2.40	2.20	2.40	2.10	2.40	-0.31	0.09	-0.16	0.00
39.1-49	2.76	2.93	3.03	2.96	2.20	2.50	2.20	2.50	-0.56	-0.43	-0.83	-0.46
49.1-59	3.44	3.21	3.57	3.57	2.30	2.60	2.00	2.30	-1.14	-0.61	-1.57	-1.27
59.1-69	-	3.99	4.56	4.06	2.60	2.80	2.50	2.50		-1.19	-2.06	-1.56
69.1-79	-	4.81	6.52	5.34	2.60	3.20	2.60	2.90		-1.61	-3.92	-2.44
79.1-89	-	-	-	6.60	2.30	3.30	3.00	3.30				-3.30
89.1-99	-	-	-	-	2.50	3.50	2.20	4.00				

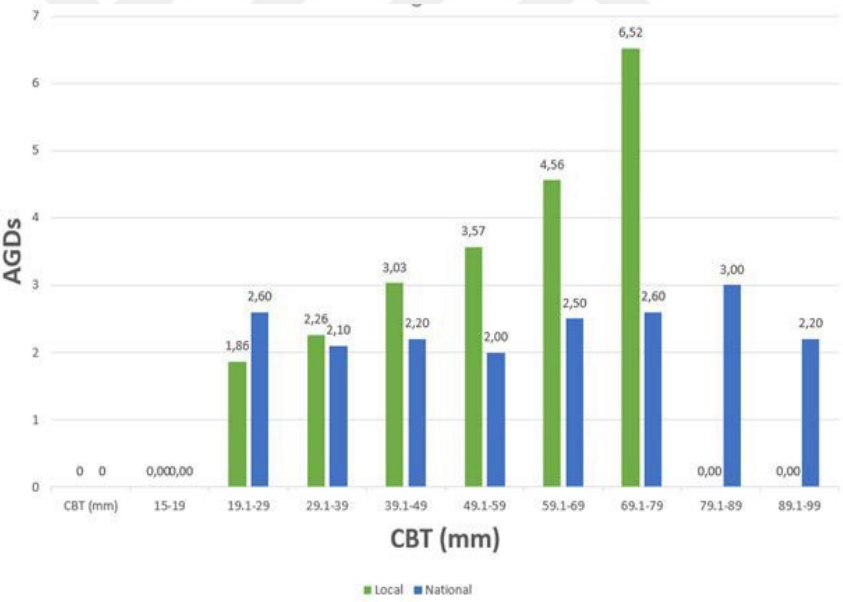
These findings are illustrated graphically in Figures 3.9 and 3.10 for CC and MLO projections, respectively. The summary of the graphical comparisons are:

(i)For CCprojections: In 40-49 age group when the CBT range was 20-29 mm, local values were close to national values, and at CBT>30mm, local values were higher than national values. In the 50-64 age group, for CBT range 20-29 mm, local values were smaller than national values, in 30-39 mm local values were close to national values, and if CBT >30 mm, local values were higher than national values. Aditionally for the both age groups, as CBT increase, the difference increases (Figure 3.9.)

(ii)For MLO projections: For the both age groups, when the CBT range was 20-29 mm, local values were smaller than national values, in 30-39 mm local values were close to national values, and if CBT>30 mm, local values were higher than national values. In addition, as CBT values increase, the difference increases (Figure 3.10.).

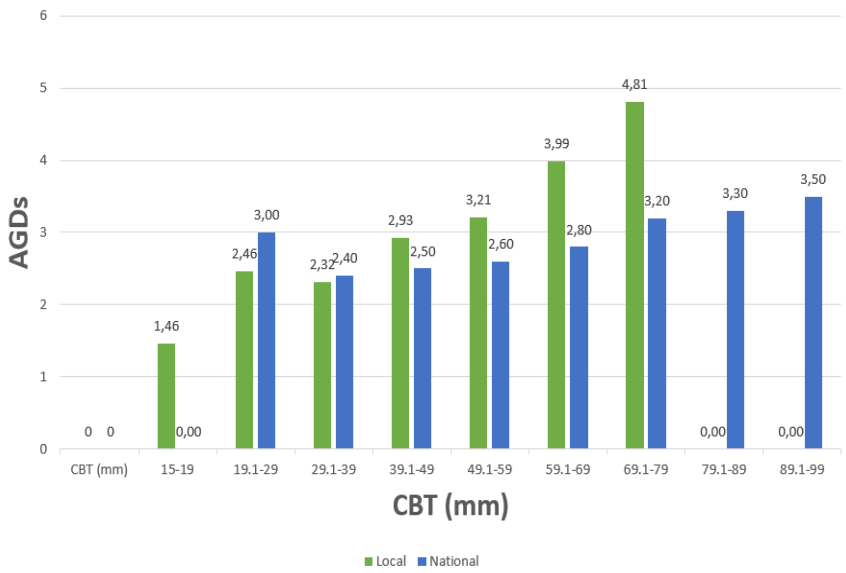


(a)Age 40-49

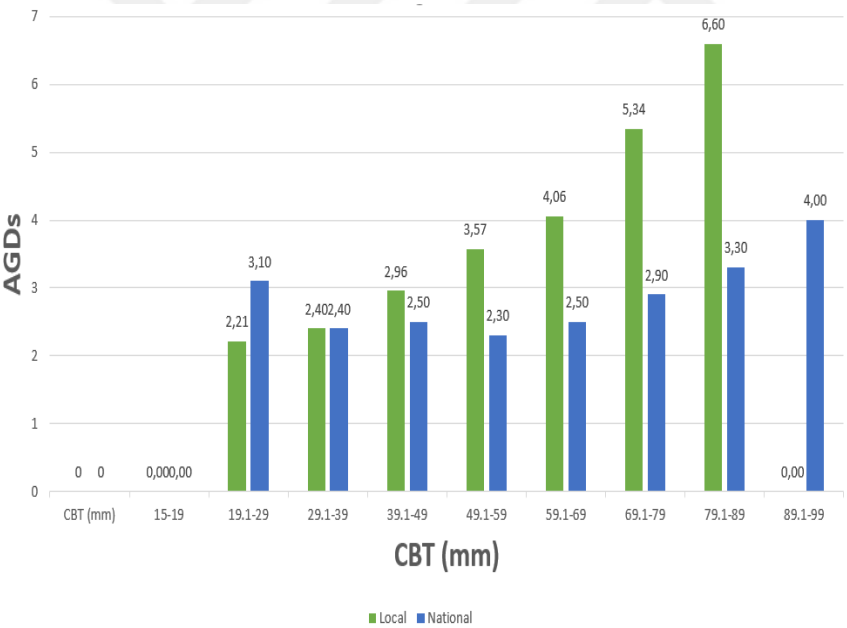


(b)Age 50-64

Figure 3.9. Comparison of AGDs(Q3) vs. CBT for national and local values (CC)



(a)Age 40-49



(b)Age 50-64

Figure 3.10. Comparison of AGDs(Q3) vs. CBT for national and local values (MLO)

(b) Analyses with respect to the Median

The median of a data set is an important indicator to understand where the equally likely division of observations take place. For this reason, we compare the 50th percentile (median-Q2) of three methods within the characteristics of age and projection types. Table 3.13 shows that Wu-Boone yielded the minimum for both projections and age groups compared to the other two methods. The highest values are observed at 2ABD method where the older ages set a higher median value for all methods. Similar evaluation was made according to the CBT groups (Table 3.14). It was observed that CBT increase showed the similar behavior as in Q3 case. 2ABD method yielded higher values for both projections and age groups compared to other two methods.

Table 3.13 The median values of three methods for age groups

		Q2 (mGy)		
Age	**Projections**	**Robson AGD**	**2ABD**	**Wu-Boone**
All	**CC**	2.36	3.37	2.06
	MLO	2.79	3.5	2.28
40-49	**CC**	2.33	3.39	2.12
	MLO	2.61	3.32	2.20
50-64	**CC**	2.37	3.37	2.01
	MLO	3.01	3.70	2.32

Table 3.14 The median values of three methods for CBT groups

		Q2 (mGy)		
CBT	**Projections**	**Robson AGD**	**2ABD**	**Wu-Boone**
19.1-29	**CC**	1.56	2.70	1.57
	MLO	1.91	2.97	1.85
29.1-39	**CC**	2.06	3.27	1.94
	MLO	1.96	3.03	1.82
39.1-49	**CC**	2.55	3.50	2.13
	MLO	2.46	3.18	2.12
49.1-59	**CC**	2.98	3.66	2.36
	MLO	3.13	3.65	2.46

Table 3.15 The mean Robson AGDs vs National (Q3) values

	Local-Mean Value				National Q3 Value			
Age	**40-49**		**50-64**		**40-49**		**50-64**	
CBT	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**	**CC**	**MLO**
15.0-19	1.89	1.97	-	-	-	-	-	-
19.1-29	1.90	2.48	1.52	1.61	2.00	3.00	2.60	3.10
29.1-39	2.15	2.09	1.98	2.13	2.20	2.40	2.10	2.40
39.1-49	2.45	2.47	2.59	2.50	2.20	2.50	2.20	2.50
49.1-59	2.78	2.74	3.01	3.17	2.30	2.60	2.00	2.30
59.1-69	3.40	3.92	3.38	3.47	2.60	2.80	2.50	2.50
69.1-79	-	4.83	-	3.46	2.60	3.20	2.60	2.90
79.1-89	-		-	3.46	2.30	3.30	3.00	3.30
89.1-99	-+	-	-	-	2.50	3.50	2.20	4.00

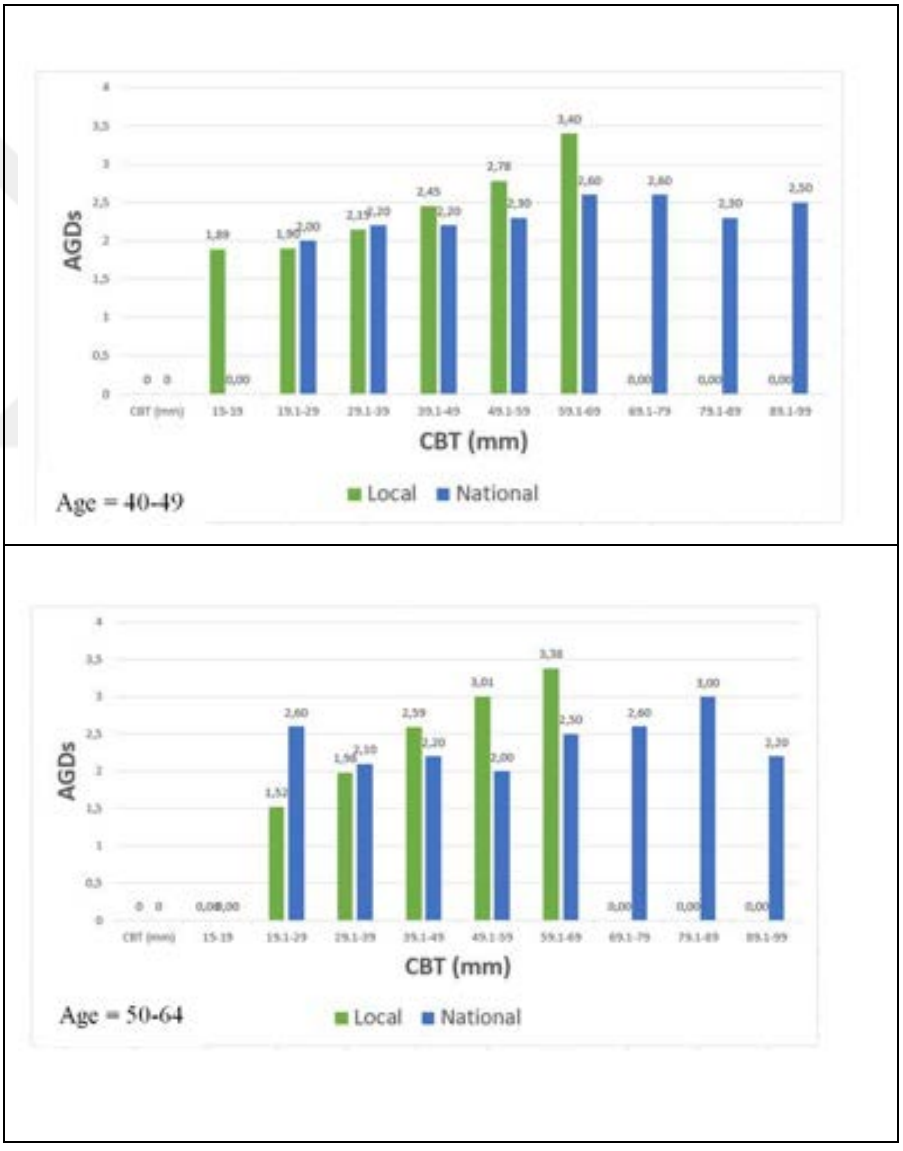
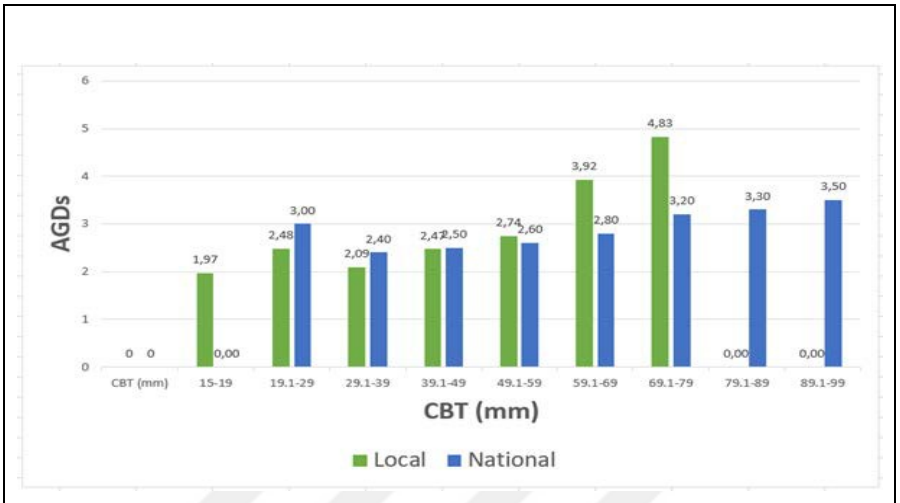
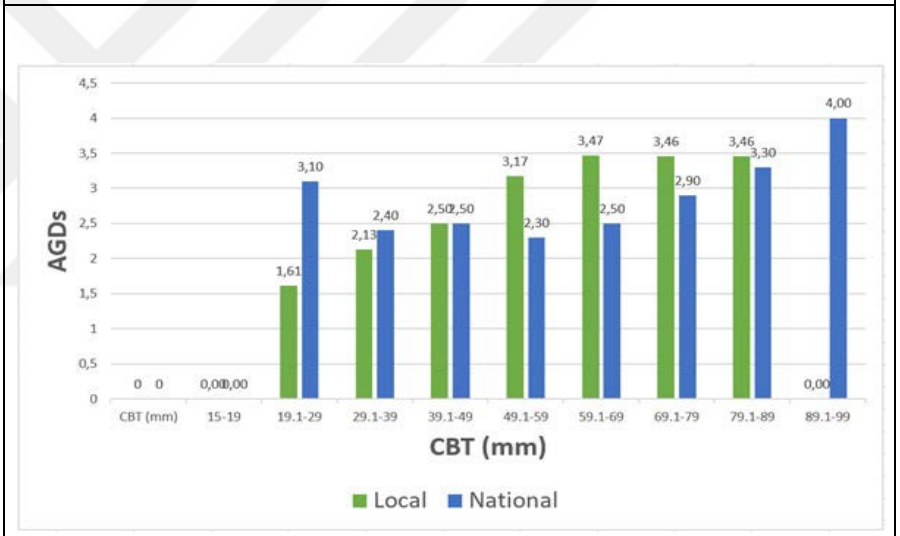


Figure 3.11. Robson AGD (Q2) vs. CBT for national and local values (CC)



(a)Age 40-49



(b)Age 50-64

Figure 3.12. Robson AGD (Q2) vs. CBT for national and local values (MLO)

(b) Analyses with respect to the Mean

As the most common statistic as a measure in data analyses, we focus on the mean AGD values obtained from each method (Table 3.15). Average values mimic the same pattern as in Q2 and Q3 analyses. The comparison of local mean values obtained using Robson AGD to national Q3 values are also presented in Table 3.13 and Figures 3.11 and 3.12.

Comparison of local arithmetic mean vs. National 75th percentile values showed that:

i. 50-64 ages require higher AGDs for both, local and national
ii. For CC, independent of age group, view local values are less than national within 20-29mm CBT was almost equivalent in 30-39mm and higher when CBT>40mm Table 3.15, Figure 3.11.
iii. For MLO, independent of age groups, local values are lower than national for CBT<40mm, almost equal for CBT=40-49mm and higher when CBT>49mm (Table 3.15, Figure 3.12).

(d)Comparative analyses using hypothesis testing

This part investigates if the selected methods yielded statistically significant AGD results when they are compared with respect to their median values. All comparisons were made for Q3 AGD values to be consistent with the literature. Four comparative approaches are considered and presented in Tables 3.16-18:

i. There exists difference between median values of projections for each selected method.
ii. There exists difference between median values of methods with respect to projection methods.
iii. There exists difference between median values of (i) and (ii) for each age groups.
iv. There exists difference between median values of (i) and (ii) for each CBT groups.

The findings showed that in 2ABD method, the projection medians do not show significant difference whereas the other did. This result did not change with respect to the age group analyses. CC vs MLO comparison for the age range 40-49 shows that with Robson -MLO is significantly high, whereas with 2ABD and Wu-Boone, there is no significant difference. For the age range 50-54 with Robson and Wu-Boone -MLO is significantly high, whereas with 2ABD there is no significant difference (Tables 3.16-18).

It is an interesting outcome to show that the comparisons with respect to different CBT (mm) ranges are not consistent with the analyses. In CC examination Robson and Wu shows no significant difference in only 19.1-29 CBT ranges

Table 3.16. Pairwise comparisons for projections and methods.

Hypothesis	Factor	p-value	Decision
CC-MLO	Robson AGD	**<0.001**	MLO is significantly higher than CC
	2ABD	0.374	No significant difference
	Wu-Boone	**<0.001**	MLO is significantly higher than CC
Robson-2ABD	CC	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.001**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone
Robson-2ABD	**MLO**	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.001**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone

Table 3.17. Pairwise comparisons with respect to age group 40-49

Age 40-49			
Hypothesis	**Factor**	**p-value**	**Decision**
CC-MLO	Robson AGD	**0.09**	MLO is significantly higher than CC
	2ABD	0.686	No significant difference
	Wu-Boone	**0.054**	MLO is significantly higher than CC
Robson-2ABD	CC	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.003**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone
Robson-2ABD	**MLO**	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.001**	Robson is significantly higher than Wu-Boone
[illegible]		**<0.001**	2ABD is significantly higher than Wu-Boone

Table 3.18. Pairwise comparisons with respect to age group 50-64

Age 40-49			
Hypothesis	**Factor**	**p-value**	**Decision**
CC-MLO	Robson AGD	**<0.01**	MLO is significantly higher than CC
	2ABD	0.158	No significant difference
	Wu-Boone	**0.003**	MLO is significantly higher than CC
Robson-2ABD	CC	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.003**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone
Robson-2ABD	**MLO**	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.001**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone

. There is no significant difference between CC and MLO values, whereas in pairwise comparison with respect to CC and MLO examination the numerical decreasing order is always 2ABD, Robson and Wu-Boone (Tables 3.19-3.22)

Table 3.19. Pairwise comparisons with respect to CBT group 19.1-29

Age 40-49			
Hypothesis	**Factor**	**p-value**	**Decision**
CC-MLO	Robson AGD	0.255	No significant difference
	2ABD	0.385	No significant difference
	Wu-Boone	0.278	No significant difference
Robson-2ABD	CC	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		0.869	No significant difference
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone
Robson-2ABD	**MLO**	0.061	No significant difference
Robson -Wu-Boone		0.922	No significant difference
2ABD-Wu-Boone		0.061	No significant difference

Table 3.20. Pairwise comparisons with respect to CBT group 29.1-39

Age 40-49			
Hypothesis	**Factor**	**p-value**	**Decision**
CC-MLO	Robson AGD	0.815	No significant difference
	2ABD	0.112	No significant difference
	Wu-Boone	0.706	No significant difference
Robson-2ABD	CC	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**0.025**	No significant difference
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone
Robson-2ABD	**MLO**	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**0.031**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone

Table 3.21. Pairwise comparisons with respect to CBT group 39.1-49

Age 40-49			
Hypothesis	**Factor**	**p-value**	**Decision**
CC-MLO	Robson AGD	0.406	No significant difference
	2ABD	0.069	No significant difference
	Wu-Boone	0.999	No significant difference
Robson-2ABD	CC	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.001**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone
Robson-2ABD	**MLO**	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.001**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone

Table 3.22. Pairwise comparisons with respect to CBT group 49.1-59

Age 40-49			
Hypothesis	**Factor**	**p-value**	**Decision**
CC-MLO	Robson AGD	0.406	No significant difference
	2ABD	0.990	No significant difference
	Wu-Boone	0.855	No significant difference
Robson-2ABD	CC	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.001**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone
Robson-2ABD	**MLO**	**<0.001**	2ABD significantly higher than Robson
Robson -Wu-Boone		**<0.001**	Robson is significantly higher than Wu-Boone
2ABD-Wu-Boone		**<0.001**	2ABD is significantly higher than Wu-Boone

CHAPTER 4

DISCUSSION AND CONCLUDING COMMENTS

This study aims firstly to compare three different dose calculation methods in order to obtain a more precise dose estimation. A complementary objective is to realize a first example for a Local DRL calculation in Turkey and comparison to National DRL values in literature [1]. The study showed that, when taking both CC and MLO projections into account, 2ABD scores are significantly higher than others. The comparisons given in Table 3.13 for projections between methods in pairs refers to:

i) 2ABD values are significantly higher than Robson AGD ($p<0.001$)
ii) 2ABD values are significantly higher than Wu-Boone ($p<0.001$)
iii) Robson AGD significantly higher than Wu-Boone ($p<0.001$)

The comparison of CC and MLO projection in terms of radiation doses shows that, MLO doses are significantly higher with Robson AGD and Wu-Boone calculation methods ($p<0.001$). While 2ABD values are not significantly different ($p=0.374$). MLO doses were higher than CC projection values in all three methods as found by Khadka S. et al. [42]. This finding is generally attributed to the anatomical presence of the pectoral muscle in the field and the low compression value of the MLO projection in general [34].

Normal distribution was studied via “Kolmogrov” test in the analysis of numeric data. Since all data did not show characteristics of normal distribution, the difference between medians of two independent group (CC - MLO) was examined via “Mann Witney U” test. The difference between more than two independent groups (Robson AGD, Wu, 2ABD) was examined via “Kruskall Wallis H test”. The data were analyzed at the level of 95% confidence level with an acceptance of that the test with the p-values less than 0.05 are to be significant. Beside of this the general appearance of the data according 75th are presented in order to compare with national values as an illustration to get a deeper insight. To

make sure that mean values of the local doses should not overpass national DRLs (third quartile of national values). Lastly the arithmetical mean of the study group for each CBT vs. related third quartile values of National DRL are compared and all of them graphically displayed (Figure 3.7. to 3.12.).

Radiation dose comparison of Robson AGD (mGy) (75th percentile) between local and national values for the age ranges 40-49 and 50-64 shows that the local values are higher with respect to national values. In the current situation local mammography screening performance cannot be proclaimed as at the expected level. The inconvenience of overdose can be related with radiology technician skill, optimization and/or mammography device originated. This emphasize the necessity of regular annual or biannual check- up, quality control and optimisation of the whole process [8,43].

The weakness of this study is using the widely accepted assumptions instead of having direct measurement for all parameters. This is also a restriction that almost all of the relatively small local mammography centers exhibit and in the daily practice, the performance of the screening would be in similar conditions using same widely accepted assumptions. Thus, this study is a nationwide, feasible practical example. On the other hand, it is generally accepted that, in the absence of the required dosimetric equipment to make direct measurements, the average glandular dosage and compressed breast thickness (CBT) can be used to present mammographic dose survey data [40].

In certain cases, ionizing radiation may result in fatal breast cancer. This necessitates dosimetric evaluation of breast screening. Their utility in comparing doses amongst mammographic systems is restricted due to their inability to accurately reflect patient dosages. If knowledge and resources are scarce, existing data on AGD and CBT maybe utilised instead [36,44]. By contrast the powerful point is the uniqueness in statistical comparisons of the three widely preferred calculation methods. Numerical values obtained by Robson AGD method is regularly in between the other two calculation methods. We did not find any result which strictly contradicts its value in the tradition.

Although Traino studied all the three methods in his paper, he included only 20 patients without precise p-values to compare the methods, and gave descriptive statistics to present the general appearance of the data for third quartile [41]. The main support for his proposition to use 2ABD is the fact that this is a practical method to be used for calculations using a digital mammography device and can be used as a surrogate of Robson AGD method. Apart from this, within our knowledge there is no paper in English literature comparing the three methods.

The inclusion of the breast density to calculations is another debate issue. Suleiman, et al. found that the use of the mammographic breast density results in underestimation of the dose from screening mammography in the context of the AGDs. The inconsistency is more apparent in smaller breast. This will in his turn cause underestimation of the radiation risk [45]. Having in mind the 2ABD method does not take the breast density into consideration, the founder of this method claims that this method's superiority is that the received doses can be automatically displayed by the digital mammography machine for each investigation as the data of kVp, mAs, breast thickness and anode-filter combination is sufficient. The standard translation and similar pattern of the graphical representation of the curves of different methods curves may end up with daily use of the 2ABD method to give a fast and approximated guess, related to received dose for digital mammography device users. On the other hand, D*g*N in Wu-Boone method, gives a direct comparison relating to risk for different equipment, and so has been employed in many parts of the world. The relationship between Ka,i and DgN are highly dependent on breast thickness and composition, as well as beam quality. Therefore, there is more variation in potential risk with the DRL quantities, such as Ka,i and Ka,e, that are measured directly than for other examinations [46]. This has been a persuasive argument for countries to use DgN to help inoptimization.

Besides, 50-50 glandularity has been an everlasting debate, since the first introduction of the concept of 50% glandularity as it may not represent the real percentage of the breast composition. Glandular vs. adipose percentage is reported as a function of CBT, age, individual variations. 50-50 model

overestimates glandularity, especially for smaller CBT, in all age groups. Unfortunately, there is no practical method on which a consensus has been established, so far [10]. For some of the authors, the average glandularity is closer to 40%, so that, 40% glandular-60% adipose ratio would be a more realistic approximation [47]. In fact, a fatty breast allows more photon penetration which leads to an underestimation of the absorbed radiation [48]. For a given CBT, AGDs increase with increasing glandularity. Individual breast glandularity calculation attempts makes the calculations inextricable.

The unconvenience of making precise measurements was a reasonable support for this rhethoric many years ago to avoid complicated calculations. The new improvements in anatomic and histologic researchs capabilities should solve this problem in a short delay. An efficient software tool may overcome this problem. Also to be mentioned that, for the same purpose there is a recent study involving the implementation of a deep learning framework [49].

Du, et al. found that doses exhibited a favorable association with CBT within a range of 20 to 60 mm. The results of the study indicated that CBT could influence the AGD through multiple pathways and these pathways represent different mechanisms [50]. Similarly, our results showed a positive correlation with AGD values for the range of 40-60 mm thickness of CBT. Conversely, in small thicknesses (20- 39 mm), the values are higher than figured out levels in 40-49 age group. The latest findings are in concordance with Suleiman, et al. [51]. In 50-64 age group positive correlation with CBT hold contrary to Suleiman's findings who emphasized the importance of the breast density which was not considered in the calculation methods used in our study.

Nakamura introduced interpolation factors to make Dance coefficients more suitable for Japanese population [52]. We cannot predict the implication of these factors the comparison of different methods because, we did not find any published data regarding Turkish women breast glandularities.

Pasicz et al., found that the AGD displayed by the mammography system and the AGD calculated following Dance method were significantly different and

depends on the anode-filter combination [45]. The change of service personnel (e.g., radiographer) of mammography also founded as modifying the difference. The inconvenience of overdose with respect to national DRL can be related with radiology technician skill, optimization and/or mammography device originated.

Kawaguchi founded that ESD (entrance surface dose) measured directly using thermoluminescent dosimeters were found 3.8 times higher than AGD and for bilateral Mammographic examination of 4 view the total dose reach the breast surface dose for CT (15.7 mGy). This very high level should also bring into consideration the total body radiation cumulated dose with yearly repetitive screenings and evidently the fate of the other neighboring organs also receiving radiation.

The attempt of inventing a semi-analytical method instead of using Monte Carlo simulation and taking primary and scattered radiation into account needs relatively complicated calculus is not widely acccepted. Thus, we did not consider it in our study [53]. An alternative way is to use a dose management software in order to predict the dose and compare with the European guidelines and optimisation [54]. Furthermore, a smartphone application needs to be introduced for fast and easy dose calculation and/or prediction to be used in daily practice in any local Screening Center.

The incoherence between the calculation methods may also be related to the inefficiency of Monte Carlo simulations which shapes all three calculation methods, but the discussion of this topic largely overpasses the scope and the capacity of this study.

Following all of the above mentioned arguments and the absence of the direct measurements, it is impossible to fully trust that each of three different calculation methods would behave in similar manner in all possible different circumstance, such as the paradoxical numerical equality between Robson and Wu calculation methods, which is only peculiar to CBT ranges 19.1-29 mm, whereas in all different CBT ranges Robson scores are significantly higher than

Wu in 50th percentile value comparison. Furthermore, the comparison of CC vs MLO with Wu calculation formula shows no significant difference in 40-49 age ranges, whereas MLO doses are calculated significantly higher in 50-64 age ranges in the 50th percentile value records. Therefore, at present mammographic dose measurements provides comparison rather than calculating individual exact doses. Meanwhile, theoretical and experimental studies should be pursued to overcome this incoherence. The main problem is the current impossibility of making direct measurement inside the breast tissue. In all fields of science, when there is not any 'Golden Rule' which overpasses the alternatives and gives persistently satisfactory results, there is a multitude of techniques and methods which, generally claims to be the most convenient one. This is the case in the dose calculation and/or estimation in mammographic screening

The definitive solution to this debate would be a creative technique and/or technology in order to get a direct radiation dose measurements in several location inside the breast. This would be most probably related to nanoscience and nanomedicine which would give us the possibility of positioning the direct radiation recording sensors exactly scientists want and remove when necessary or producing self-resorbing biodegradable and biocompatible sensors. This also may be a nanoelectronic device implantable noninvasively or mini invasively. Another option might be a nanochemical and/or nanomolecular new materials discoveries which would help indirectly to quantify the radiation dose inside the breast tissue.

In conclusion, starting from the fact that the chance of developing deadly cancer after receiving a glandular dosage of 2 mGy is about 1 in 50,000 (0.002%) in a woman aged 50 to 65, radiation dose justification and optimization in mammography should be seriously investigated.

The interdisciplinary research area dealing with this dilemma is closely related with Biomedical Engineering in the sense to depict the radiation doses, their methods of quantification and the influence on diagnosing breast cancer

accurately. This study contributes to the literature on the elaboration of dose using real life data. The main objectives of this study are achieved by

i) Exposing the numerical incompatibility of the three different dose calculation methods in increasing order Wu-Boone, Robson AGD and 2ABD with significant differences ($p<0.05$)

ii) Giving the first local vs national Average Glandular Dose comparison of the country in order to strengthen and complete the earlier study which aim the national standards declaration by the national radiation protection authority.

To overcome the confusion of several calculation methods, we anticipate the introduction of a new creative technique and/or technology in order to get a direct radiation dose measurements in several location inside of the breast.

As future study, also a work on the invention of a new diagnostic tools of breast cancer which are noninvasive should be caried out. Nanosciences and biological markers are seemingly the two of the main field of interest to reach this goal. By that time, scientific community should keep on theoretical and experimental efforts to resolve the incompatibility between the dosage calculation formulae.

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APPENDICES

A Factors Generated by Monte Carlo Simulation for Robson Method [8]

Table A.1. 'g factor' (incident Kerma) to AGD conversion factor in 50% glandularity for HVL and CBT.

CBT (cm)	HVL (mmAl)										
	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8
2	0.390	0.433	0.473	0.509	0.543	0.573	0.587	0.622	0.644	0.663	0.682
3	0.274	0.309	0.342	0.374	0.406	0.437	0.466	0.491	0.514	0.535	0.555
4	0.207	0.235	0.261	0.289	0.318	0.346	0.374	0.399	0.421	0.441	0.460
5	0.164	0.187	0.209	0.232	0.258	0.287	0.310	0.332	0.352	0.371	0.389
6	0.135	0.154	0.172	0.192	0.214	0.236	0.261	0.282	0.300	0.317	0.333
7	0.114	0.130	0.145	0.163	0.177	0.202	0.224	0.244	0.259	0.274	0.289
8	0.098	0.112	0.126	0.140	0.154	0.175	0.195	0.212	0.227	0.241	0.254
9	0.086	0.098	0.111	0.123	0.136	0.154	0.172	0.188	0.202	0.214	0.227
10	0.076	0.087	0.099	0.110	0.121	0.138	0.154	0.138	0.181	0.193	0.204
11	0.069	0.079	0.089	0.099	0.109	0.124	0.139	0.152	0.164	0.175	0.186

Table A.2. 'c factors' for Women in Age Group 40-49.

CBT (cm)	HVL (mmAl)										
	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8
2	0.885	0.891	0.9	0.905	0.91	0.914	0.919	0.923	0.928	0.932	0.936
3	0.925	0.929	0.931	0.933	0.937	0.94	0.941	0.947	0.95	0.953	0.956
4	1	1	1	1	1	1	1	1	1	1	1
5	1.086	1.082	1.081	1.078	1.075	1.071	1.069	1.064	1.06	1.057	1.053
6	1.164	1.16	1.151	1.15	1.144	1.139	1.134	1.124	1.117	1.111	1.103
7	1.232	1.225	1.214	1.208	1.204	1.196	1.188	1.176	1.167	1.157	1.147
8	1.275	1.265	1.257	1.254	1.247	1.237	1.227	1.213	1.202	1.191	1.179
9	1.299	1.292	1.282	1.275	1.27	1.26	1.249	1.236	1.225	1.213	1.2
10	1.307	1.298	1.29	1.286	1.283	1.272	1.261	1.248	1.236	1.224	1.211
11	1.306	1.301	1.294	1.291	1.283	1.274	1.266	1.251	1.24	1.228	1.215

Table A.3. 'c factors' for Women in Age Group 50-64.

CBT (cm)	HVL (mmAl)										
	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	0.8
2	0.885	0.891	0.9	0.905	0.91	0.914	0.919	0.923	0.928	0.932	0.936
3	0.894	0.898	0.903	0.906	0.911	0.915	0.918	0.924	0.928	0.933	0.937
4	0.94	0.943	0.945	0.947	0.948	0.952	0.955	0.956	0.959	0.961	9.64
5	1.005	1.005	1.005	1.004	1.004	1.004	1.004	1.004	1.003	1.003	1.003
6	1.08	1.078	1.074	1.074	1.071	1.068	1.066	1.061	1.058	1.055	1.051
7	1.152	1.147	1.141	1.138	1.135	1.13	1.127	1.117	1.111	1.105	1.098
8	1.22	1.213	1.206	1.205	1.199	1.19	1.183	1.172	1.163	1.154	1.145
9	1.27	1.264	1.254	1.248	1.244	1.235	1.225	1.214	1.204	1.193	1.181
10	1.295	1.287	1.279	1.275	1.272	1.262	1.251	1.238	1.227	1.215	1.203
11	1.294	1.29	1.283	1.281	1.273	1.264	1.256	1.242	1.232	1.22	1.208

B Randomly selected DGs for CC and MLO projections

Project	Age	CBT	ESD	AGD	Ka,i	CBT	2ABD	FSD	ESAK	CBT	Dg
LCC	49	1.5	3.94	1.38	4.8299	1.5	2.63	62.50	3.60	1.5	1.43
RMLO	49	1.5	4.07	1.43	4.9832	1.5	2.72	62.50	3.71	1.5	1.48
LMLO	49	1.5	4.26	1.49	5.2132	1.5	2.84	62.50	3.89	1.5	1.55
RCC	42	1.5	3.38	1.19	4.1399	1.5	2.26	62.50	3.09	1.5	1.23
LCC	42	1.5	1.88	0.66	2.3000	1.5	1.25	62.50	1.71	1.5	0.68
RCC	49	1.6	3.71	1.26	4.5373	1.6	2.39	62.40	3.38	1.6	1.30
RCC	42	1.7	4.52	1.55	5.5946	1.7	2.85	62.30	4.11	1.7	1.62
RMLO	42	1.7	5.63	1.94	6.9687	1.7	3.55	62.30	5.12	1.7	2.01
RCC	41	1.7	6.64	2.15	7.9300	1.7	4.03	62.30	6.07	1.7	2.15
RCC	44	1.8	16.26	6.09	14.1022	1.8	7.85	62.20	14.63	1.8	5.97
LCC	44	1.8	16.32	6.12	14.1570	1.8	7.88	62.20	14.69	1.8	5.99
LCC	41	1.8	6.38	2.00	7.6205	1.8	3.75	62.20	5.83	1.8	1.99
RCC	49	1.8	1.30	0.23	0.7883	1.8	0.39	62.20	1.01	1.8	0.32
LMLO	49	1.8	2.17	0.44	2.8076	1.8	1.38	62.20	1.90	1.8	0.65
LMLO	41	1.9	5.89	1.79	7.0408	1.9	3.35	62.10	5.39	1.9	1.78
RCC	61	1.9	3.25	1.02	5.7283	1.9	2.73	62.10	2.98	1.9	1.09
LCC	45	2	13.83	3.12	11.7981	2	6.20	62.00	11.51	2	2.64
LCC	43	2	4.77	1.44	5.8401	2	2.69	62.00	4.35	2	1.44
RCC	44	2	5.10	0.91	7.0342	2	3.24	62.00	4.07	2	1.44
LCC	44	2	6.33	1.98	7.8268	2	3.60	62.00	5.75	2	2.04
RCC	64	2	0.99	0.29	1.1332	2	0.52	62.00	0.91	2	0.28
RCC	64	2.1	4.43	1.51	3.6239	2.1	1.85	61.90	4.00	2.1	1.42
RCC	60	2.1	9.32	2.88	11.5285	2.1	5.14	61.90	8.48	2.1	2.90
RMLO	41	2.1	8.11	2.36	9.9202	2.1	4.42	61.90	7.40	2.1	2.37
RMLO	43	2.2	8.87	2.60	10.9665	2.2	4.74	61.80	8.06	2.2	2.67
LCC	49	2.2	1.53	0.47	2.0983	2.2	0.91	61.80	1.42	2.2	0.42
LCC	61	2.2	5.03	1.65	6.2808	2.2	2.71	61.80	4.62	2.2	1.53
RMLO	42	2.2	5.56	1.63	6.8790	2.2	2.97	61.80	5.06	2.2	1.67
LMLO	42	2.2	5.56	1.63	6.8790	2.2	2.97	61.80	5.06	2.2	1.67
RCC	42	2.2	0.60	0.16	0.6842	2.2	0.30	61.80	0.55	2.2	0.15
LCC	64	2.2	0.85	0.23	0.9693	2.2	0.42	61.80	0.78	2.2	0.22
RCC	40	2.3	5.17	1.37	6.1789	2.3	2.59	61.70	4.73	2.3	1.35
LCC	50	2.3	6.23	1.81	7.7007	2.3	3.23	61.70	5.66	2.3	1.81
LMLO	61	2.3	4.93	1.27	6.0005	2.3	2.51	61.70	4.41	2.3	1.41
LMLO	42	2.4	8.85	2.41	10.9353	2.4	4.44	61.60	8.04	2.4	2.49

C SPSS Outputs for Comparative Statistical Analyses

This part illustrates the results of Mann Whitney U tests

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
Robson_AGD	CC	253	223.79	56618.00
	MLO	253	283.21	71653.00
	Total	506		
ABD	CC	253	247.72	62672.50
	MLO	253	259.28	65598.50
	Total	506		
Wu_AGD	CC	253	230.62	58347.00
	MLO	253	276.38	69924.00
	Total	506		

Test Statistics[a]

	Robson_AGD	ABD	Wu_AGD
Mann-Whitney U	24487.000	30541.500	26216.000
Wilcoxon W	56618.000	62672.500	58347.000
Z	-4.571	-.890	-3.520
Asymp. Sig. (2-tailed)	.000	.374	.000

a. Grouping Variable: Grup

All-(CC-MLO)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	253	182.71	46226.00
	2ABD	253	324.29	82045.00
	Total	506		

Test Statistics[a]

	mGy
Mann-Whitney U	14095.000
Wilcoxon W	46226.000
Z	-10.891
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	253	287.26	72677.50
	Wu-Boone	253	219.74	55593.50
	Total	506		

Test Statistics[a]

	mGy
Mann-Whitney U	23462.500
Wilcoxon W	55593.500
Z	-5.194
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	253	347.27	87860.00
	Wu-Boone	253	159.73	40411.00
	Total	506		

Test Statistics[a]

	mGy
Mann-Whitney U	8280.000
Wilcoxon W	40411.000
Z	-14.427
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	253	207.79	52572.00
	2ABD	253	299.21	75699.00
	Total	506		

Test Statistics[a]

	mGy
Mann-Whitney U	20441.000
Wilcoxon W	52572.000
Z	-7.032
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	253	295.37	74729.00
	Wu-Boone	253	211.63	53542.00
	Total	506		

Test Statistics[a]

	mGy
Mann-Whitney U	21411.000
Wilcoxon W	53542.000
Z	-6.442
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	253	337.57	85404.00
	Wu-Boone	253	169.43	42867.00
	Total	506		

Test Statistics[a]

	mGy
Mann-Whitney U	10736.000
Wilcoxon W	42867.000
Z	-12.933
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
Robson_AGD	CC	119	107.86	12835.50
	MLO	119	131.14	15605.50
	Total	238		
ABD	CC	119	121.31	14435.50
	MLO	119	117.69	14005.50
	Total	238		
Wu_AGD	CC	119	110.90	13197.00
	MLO	119	128.10	15244.00
	Total	238		

Test Statistics[a]

	Robson_AGD	ABD	Wu_AGD
Mann-Whitney U	5695.500	6865.500	6057.000
Wilcoxon W	12835.500	14005.500	13197.000
Z	-2.608	-.405	-1.927
Asymp. Sig. (2-tailed)	.009	.686	.054

a. Grouping Variable: Grup

Age 40-49 –(CC-MLO)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
Robson_AGD	CC	134	116.55	15617.50
	MLO	134	152.45	20428.50
	Total	268		
ABD	CC	134	127.82	17127.50
	MLO	134	141.18	18918.50
	Total	268		
Wu_AGD	CC	134	120.53	16151.00
	MLO	134	148.47	19895.00
	Total	268		

Test Statistics[a]

	Robson_AGD	ABD	Wu_AGD
Mann-Whitney U	6572.500	8082.500	7106.000
Wilcoxon W	15617.500	17127.500	16151.000
Z	-3.792	-1.412	-2.951
Asymp. Sig. (2-tailed)	.000	.158	.003

a. Grouping Variable: Grup

Age 50-64 –(CC-MLO)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	119	81.99	9756.50
	2ABD	119	157.01	18684.50
	Total	238		

Test Statistics[a]

	mGy
Mann-Whitney U	2616.500
Wilcoxon W	9756.500
Z	-8.406
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-Age-40-49-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	119	132.87	15812.00
	Wu-Boone	119	106.13	12629.00
	Total	238		

Test Statistics[a]

	mGy
Mann-Whitney U	5489.000
Wilcoxon W	12629.000
Z	-2.997
Asymp. Sig. (2-tailed)	.003

a. Grouping Variable: Grup

CC-Age-40-49-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	119	164.71	19600.50
	Wu-Boone	119	74.29	8840.50
	Total	238		

Test Statistics[a]

	mGy
Mann-Whitney U	1700.500
Wilcoxon W	8840.500
Z	-10.131
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-Age-40-49-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	134	100.94	13525.50
	2ABD	134	168.06	22520.50
	Total	268		

Test Statistics[a]

	mGy
Mann-Whitney U	4480.500
Wilcoxon W	13525.500
Z	-7.089
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-Age 50-64-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	134	154.80	20743.00
	Wu-Boone	134	114.20	15303.00
	Total	268		

Test Statistics[a]

	mGy
Mann-Whitney U	6258.000
Wilcoxon W	15303.000
Z	-4.287
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-Age 50-64-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	134	183.10	24535.00
	Wu-Boone	134	85.90	11511.00
	Total	268		

Test Statistics[a]

	mGy
Mann-Whitney U	2466.000
Wilcoxon W	11511.000
Z	-10.264
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-Age 50-64-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	119	95.70	11388.00
	2ABD	119	143.30	17053.00
	Total	238		

Test Statistics[a]

	mGy
Mann-Whitney U	4248.000
Wilcoxon W	11388.000
Z	-5.334
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO-Age-40-49-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	119	135.17	16085.00
	Wu-Boone	119	103.83	12356.00
	Total	238		

Test Statistics[a]

	mGy
Mann-Whitney U	5216.000
Wilcoxon W	12356.000
Z	-3.511
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO-Age-40-49-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	119	158.66	18880.00
	Wu-Boone	119	80.34	9561.00
	Total	238		

Test Statistics[a]

	mGy
Mann-Whitney U	2421.000
Wilcoxon W	9561.000
Z	-8.774
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO-Age-40-49-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	134	111.21	14902.50
	2ABD	134	157.79	21143.50
	Total	268		

Test Statistics[a]

	mGy
Mann-Whitney U	5857.500
Wilcoxon W	14902.500
Z	-4.919
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO-Age-50-64-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	134	160.71	21535.50
	Wu-Boone	134	108.29	14510.50
	Total	268		

Test Statistics[a]

	mGy
Mann-Whitney U	5465.500
Wilcoxon W	14510.500
Z	-5.537
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO-Age-50-64-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	134	179.59	24065.00
	Wu-Boone	134	89.41	11981.00
	Total	268		

Test Statistics[a]

	mGy
Mann-Whitney U	2936.000
Wilcoxon W	11981.000
Z	-9.524
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO-Age-50-64-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
Robson_AGD	CC	24	16.67	400.00
	MLO	11	20.91	230.00
	Total	35		
ABD	CC	24	16.94	406.50
	MLO	11	20.32	223.50
	Total	35		
Wu_AGD	CC	24	16.73	401.50
	MLO	11	20.77	228.50
	Total	35		

Test Statistics[a]

	Robson_AGD	ABD	Wu_AGD
Mann-Whitney U	100.000	106.500	101.500
Wilcoxon W	400.000	406.500	401.500
Z	-1.137	-.906	-1.084
Asymp. Sig. (2-tailed)	.255	.365	.278

a. Grouping Variable: Grup

CBT 19.1-29-(CC-MLO)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
Robson_AGD	CC	61	50.02	3051.50
	MLO	37	48.64	1799.50
	Total	98		
ABD	CC	61	53.06	3236.50
	MLO	37	43.64	1614.50
	Total	98		
Wu_AGD	CC	61	50.34	3071.00
	MLO	37	48.11	1780.00
	Total	98		

Test Statistics[a]

	Robson_AGD	ABD	Wu_AGD
Mann-Whitney U	1096.500	911.500	1077.000
Wilcoxon W	1799.500	1614.500	1780.000
Z	-.235	-1.590	-.377
Asymp. Sig. (2-tailed)	.815	.112	.706

a. Grouping Variable: Grup

CBT 29.1-39-(CC-MLO)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
Robson_AGD	CC	98	83.54	8187.00
	MLO	67	82.21	5508.00
	Total	165		
ABD	CC	98	88.80	8702.00
	MLO	67	74.52	4993.00
	Total	165		
Wu_AGD	CC	98	83.04	8138.00
	MLO	67	82.94	5557.00
	Total	165		

Test Statistics[a]

	Robson_AGD	ABD	Wu_AGD
Mann-Whitney U	3230.000	2715.000	3279.000
Wilcoxon W	5508.000	4993.000	5557.000
Z	-.176	-1.885	-.013
Asymp. Sig. (2-tailed)	.860	.059	.989

a. Grouping Variable: Grup

CBT 39.1-49-(CC-MLO)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
Robson_AGD	CC	56	61.41	3439.00
	MLO	72	66.90	4817.00
	Total	128		
ABD	CC	56	64.46	3609.50
	MLO	72	64.53	4646.50
	Total	128		
Wu_AGD	CC	56	62.84	3519.00
	MLO	72	65.79	4737.00
	Total	128		

Test Statistics[a]

	Robson_AGD	ABD	Wu_AGD
Mann-Whitney U	1843.000	2013.500	1923.000
Wilcoxon W	3439.000	3609.500	3519.000
Z	-.831	-.012	-.447
Asymp. Sig. (2-tailed)	.406	.990	.655

a. Grouping Variable: Grup

CBT 49.1-59-(CC-MLO)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	24	17.13	411.00
	2ABD	24	31.88	765.00
	Total	48		

Test Statistics[a]

	mGy
Mann-Whitney U	111.000
Wilcoxon W	411.000
Z	-3.650
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-19.1-29-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	24	24.83	596.00
	Wu-Boone	24	24.17	580.00
	Total	48		

Test Statistics[a]

	mGy
Mann-Whitney U	280.000
Wilcoxon W	580.000
Z	-.165
Asymp. Sig. (2-tailed)	.869

a. Grouping Variable: Grup

CC-CBT-19.1-29-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	24	32.15	771.50
	Wu-Boone	24	16.85	404.50
	Total	48		

Test Statistics[a]

	mGy
Mann-Whitney U	104.500
Wilcoxon W	404.500
Z	-3.784
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-19.1-29-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	61	36.49	2226.00
	2ABD	61	86.51	5277.00
	Total	122		

Test Statistics[a]

	mGy
Mann-Whitney U	335.000
Wilcoxon W	2226.000
Z	-7.812
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-29.1-39-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	61	68.66	4188.50
	Wu-Boone	61	54.34	3314.50
	Total	122		

Test Statistics[a]

	mGy
Mann-Whitney U	1423.500
Wilcoxon W	3314.500
Z	-2.238
Asymp. Sig. (2-tailed)	.025

a. Grouping Variable: Grup

CC-CBT-29.1-39-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	61	88.19	5379.50
	Wu-Boone	61	34.81	2123.50
	Total	122		

Test Statistics[a]

	mGy
Mann-Whitney U	232.500
Wilcoxon W	2123.500
Z	-8.337
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-29.1-39-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	98	66.49	6516.50
	2ABD	98	130.51	12789.50
	Total	196		

Test Statistics[a]

	mGy
Mann-Whitney U	1665.500
Wilcoxon W	6516.500
Z	-7.899
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-39.1-49-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	98	118.09	11573.00
	Wu-Boone	98	78.91	7733.00
	Total	196		

Test Statistics[a]

	mGy
Mann-Whitney U	2882.000
Wilcoxon W	7733.000
Z	-4.836
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-39.1-49-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	98	138.67	13589.50
	Wu-Boone	98	58.33	5716.50
	Total	196		

Test Statistics[a]

	mGy
Mann-Whitney U	865.500
Wilcoxon W	5716.500
Z	-9.914
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-39.1-49-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	56	45.59	2553.00
	2ABD	56	67.41	3775.00
	Total	112		

Test Statistics[a]

	mGy
Mann-Whitney U	957.000
Wilcoxon W	2553.000
Z	-3.556
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-49.1-59-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	56	69.57	3896.00
	Wu-Boone	56	43.43	2432.00
	Total	112		

Test Statistics[a]

	mGy
Mann-Whitney U	836.000
Wilcoxon W	2432.000
Z	-4.260
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-49.1-59-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	56	75.38	4221.50
	Wu-Boone	56	37.62	2106.50
	Total	112		

Test Statistics[a]

	mGy
Mann-Whitney U	510.500
Wilcoxon W	2106.500
Z	-6.154
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

CC-CBT-49.1-59-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	11	8.91	98.00
	2ABD	11	14.09	155.00
	Total	22		

Test Statistics[a]

	mGy
Mann-Whitney U	32.000
Wilcoxon W	98.000
Z	-1.871
Asymp. Sig. (2-tailed)	.061

a. Grouping Variable: Grup

MLO-CBT-19.1-29-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	11	11.64	128.00
	Wu-Boone	11	11.36	125.00
	Total	22		

Test Statistics[a]

	mGy
Mann-Whitney U	59.000
Wilcoxon W	125.000
Z	-.098
Asymp. Sig. (2-tailed)	.922

a. Grouping Variable: Grup

MLO -CBT-19.1-29-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	11	14.09	155.00
	Wu-Boone	11	8.91	98.00
	Total	22		

Test Statistics[a]

	mGy
Mann-Whitney U	32.000
Wilcoxon W	98.000
Z	-1.871
Asymp. Sig. (2-tailed)	.061

a. Grouping Variable: Grup

MLO -CBT-19.1-29-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	37	23.28	861.50
	2ABD	37	51.72	1913.50
	Total	74		

Test Statistics[a]

	mGy
Mann-Whitney U	158.500
Wilcoxon W	861.500
Z	-5.687
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO -CBT-29.1-39-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	37	42.88	1586.50
	Wu-Boone	37	32.12	1188.50
	Total	74		

Test Statistics[a]

	mGy
Mann-Whitney U	485.500
Wilcoxon W	1188.500
Z	-2.152
Asymp. Sig. (2-tailed)	.031

a. Grouping Variable: Grup

MLO -CBT-29.1-39-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	37	52.70	1950.00
	Wu-Boone	37	22.30	825.00
	Total	74		

Test Statistics[a]

	mGy
Mann-Whitney U	122.000
Wilcoxon W	825.000
Z	-6.081
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO -CBT-29.1-39-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	67	49.49	3316.00
	2ABD	67	85.51	5729.00
	Total	134		

Test Statistics[a]

	mGy
Mann-Whitney U	1038.000
Wilcoxon W	3316.000
Z	-5.369
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO -CBT-39.1-49-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	67	80.15	5370.00
	Wu-Boone	67	54.85	3675.00
	Total	134		

Test Statistics[a]

	mGy
Mann-Whitney U	1397.000
Wilcoxon W	3675.000
Z	-3.772
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO -CBT-39.1-49-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	67	93.41	6258.50
	Wu-Boone	67	41.59	2786.50
	Total	134		

Test Statistics[a]

	mGy
Mann-Whitney U	508.500
Wilcoxon W	2786.500
Z	-7.725
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO -CBT-39.1-49-(2ABD-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	72	55.51	3996.50
	2ABD	72	89.49	6443.50
	Total	144		

Test Statistics[a]

	mGy
Mann-Whitney U	1368.500
Wilcoxon W	3996.500
Z	-4.889
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO -CBT-49.1-59-(Robson-2ABD)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	Robson	72	94.80	6825.50
	Wu-Boone	72	50.20	3614.50
	Total	144		

Test Statistics[a]

	mGy
Mann-Whitney U	986.500
Wilcoxon W	3614.500
Z	-6.415
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO -CBT-49.1-59-(Robson-Wu)

Mann-Whitney Test

Ranks

	Grup	N	Mean Rank	Sum of Ranks
mGy	2ABD	72	102.14	7354.00
	Wu-Boone	72	42.86	3086.00
	Total	144		

Test Statistics[a]

	mGy
Mann-Whitney U	458.000
Wilcoxon W	3086.000
Z	-8.527
Asymp. Sig. (2-tailed)	.000

a. Grouping Variable: Grup

MLO -CBT-49.1-59-(2ABD-Wu)

CURRICULUM VITAE

AHMET EGE

Education:

High School : Galatasaray High School - Istanbul Turkey 1971-1979 University :1.Medical School- Ege University -Izmir- Turkey1979-1985

2.Arts and Sciences Faculty. Pysics Dept -METU-Ankara-Turkey

2011-2019 Post Graduate 1.Dept.Orthopaedic Surgery and Traumatology Ankara Uni. Medical School -Ankara -Turkey 1987-1992

2.Biomedical Engineering Dept.PhD student METU-Ankara-Turkey

2011 to present

Degrees

Medical Doctor (MD) 1985

Orthopaedic Surgeon (Orthopaedics and Traumatology) 1992

Hand Surgeon (Hand and Upper Ekstremity) Approval No:90652-2011 Physicist (Bachelor of Science) 2018

Professional Experience

- Chairman, Department Orthopaedic Surgery and Traumatology Ufuk University Medical School, Ankara Turkey 2012-2018
- Prof. Dr, Ufuk Üniv. Medical School.(Ankara). Orthopaedic Surgery and Traumatology March 2012-April2021
- Visiting Fellow, Peripheral Nerve Surgery Unit Royal National Orthopaedic Hospital (RNOH) London, England July 2011-October 2011
- Chairman, Department Orthopaedic Surgery and Traumatology Bülent Ecevit University Medical School Zonguldak Turkey, 2001 -2012
- Visiting Fellow, Ege Üniv.Medical School. Neurochirurgy Dept.Spinal Surgery Group(Dr. Mehmet Zileli) 1 March 2008-31 March 2008
- Visiting Fellow, Ege Üniv.Medical School. Orthopaedic Surgery and Traumatology. Orthopaedic Oncology Group (Dr. Dündar SABAH) 05 July2004- 03September2004
- Visiting Fellow, Sports Traumatology and Arthroscopic Surgery Villa Stuart , Institut of Motor Sciences. Rome, Italy (Director:Pier Paola MARIANI M.D),

July 2000-January 2002

- Assistant Professor, Associate Professor, Professor Dept. Orthopedic Surgery and Traumatology Bülent Ecevit Univ. Zonguldak , Turkey, June 2000-March 2012
- Chief, Hand Surgery Department Çankaya Hospital Ankara , March 1998-September1999
- Clinical Fellow , Instıtut of the Hand Surgery , Paris FRANCE (Director: Alain GİLBERT M.D.), April 1997-October 1997Part-time partner ,Ankara Hand Surgery Center (Director: Ömer ERÇETİNM.D.), November1994-November1996
- Chief Resident, Departement of Traumatology and Orthopedics (Director: Savaş AGAOGLU M.D.), October1994-Décember 1999
- Clinical Fellow , Spine Surgery Departement-Institut Calot-Berck FRANCE as Spine Surgery (Director: Daniel CHOPIN M.D), September.l993-September.1994
- Obligatory Service, Clinic of Traumatology and Orthopaedics-State Hospital Adıyaman TURKEY , February.1993-September.1993
- Visiting Hand Surgery Fellow, Department of Hand Surgery, Columbia University Presbyterian Hospital New York USA (Director: Robert E. CARROLL M.D.), October1990-December. 1991
- Obligatory Service, State HospitalEmergency Service Department, KayseriTurkey, September 1985-February 1986

Language Skills

English and French (Fluents). German (Level B)

- Government Foreign Language Exam

  French 97-93(KPDS Foreign Language Test Score) English 90 (KPDS Language Exam-Test Score-2004) 85(YDS Foreign Language Test Score-2020)

  Advanced Communication Skills Grade AA- 2018 METU

  Hacettepe Univ Preparatory Language School Graduate in German (Grade A3) 2021

National Patents

- Usefull Model (Faydalı Model) TR-1996 00985 Y-Turkish Patent Institute
  - Turkish Patent Institut (TPE).20.2.1997-98/01685

International Patents

1.United States Patent Office USPTO No: 6,284,000.B1 Mayıs 2001. (Patent owner:Ahmet EGE).

2. Russian Federation Eurasian patent no:001281. (Patent owner:Ahmet EGE).(2001)

Memberships

- Trafik Kazaları Yardım Vakfı
- Turkish Orthopedic Surgery and TraumatologyAssociation
- Turkish Orthopaedic Surgery and Traumatology Educational Council (TOTEK)member
- TurkishHand Surgery Association.
- Robert E. Carroll İnternational Fellowship(NYC-USA)
- Raoul Toubiana Hand Club (Paris-France)Board Examination

(Turkish Orthopaedic Association Proficiency Exam.): 07 August 2003 Theorical and 27 August 2003 Practical Board Examination Certificate.

Turkish Orthopaedic Association Educational Commission (TOTEK) Member/Certificate

Publications

A. International Journals

A1. A. Ege, İ. Tuncay, O. Ercetin "Foucher`s first dorsal metacarpal artery (DMCA) flap (Evaluation of 21 cases)" Isr Med Assoc J. 2002 Jun;4(6):421-3.Endeks:SCI-Expanded

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fractures of the humerus (a radiological study), Arch Orthop Trauma Surg, 128(7),(2008)Endeks:SCI-Expanded

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A8.Turhan, E., A. Ege, S. Keser ve A Bayar, Elephantiasis nostras verrucosa complicated with chronic tibial osteomyelitis. Arch Orthop Trauma Surg, 128 (10),(2008) Endeks: SCI-Expanded ISSN:0936-8051 doi:10.1007/s00402-007-0498-1

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A 10. Bayar, A., S. Sarıkaya, S. Keser, Ş. Özdolap, İ. Tuncay ve A. Ege, Regional bone density changes in anterior cruciate ligament deficient knees: a DEXA study. Knee, 15(5), (2008) Endeks:SCI-Expanded

A 11. Bayar, A., İ Tuncay, N. Atasoy, H. Ayoğlu, S. Keser ve A. Ege, The effect of watching live arthroscopıc views on postoperative anxiety of patients. Knee Surg Sports Traumatol Arthrosc, 16(11), (2008)Endeks:SSCI ISSN:0942-2056 doi:10.1007/s00167-008-0576-0

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B. International Congress Proceedings BooksPublications

B1. M. Akıncı, Ö. Erçetin, A. Ege, "A New Approach in the Treatment of Macrodactyly", 6. Dünya El Cerrahisi Kongre Kitabı – 1995

B2. İ. Ökçesiz, D. Özer, A. Ege , A. Thumb Reconstruction Using Two Free Flaps. (Poster), 6. Dünya El Cerrahisi Kongresi, Finlandiya,1995

B3. Y. Önem, B. Atilla, A. Çalışır, A. Ege, "Nörölojik Defisiti Olmayan Torakolumber Burst ve Kompresyon Kırıklarının Konservatif Tedavisinin Karşılaştırılması" SICOT Bölgesel Kongresi Kitabı, 1996

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B6. A. Ege, C. Ege, "A New Concept and Design in Wrist Reconstruction", 8th Congress of the International Federation of Societies For Surgery Of The Hand. Congressbook , 2001

B7. İE Ökçesiz, S Tufan, A Ege "Heterotopik nerve coaptation with terminolateral nöroraphy in avulsed amputations." 6th Congress European Federation for Microsurgery, 20-23 Haziran 2003, İstanbul

B8. Tuncay İ., A. Ege ve S. Keser, "Humeral bone transfer in a mental retardate patient" 3rd Meeting of the A.S.A.M.I international, Istanbul, 2004

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I Kienböck disease" 3rd Meeting of the A.S.A.M.I international, Istanbul, 2004

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Other

-Three Thesis Advisorshipsin Orthopaedic Surgery and Traumatology

- Several National and İnternational Congress and Courses Participation
- Several National Papers and Congress Paper Presentations and Publications
- Two National Books Chapters
- Traduction to Turkish of a Scientific Textbook Chapter