ENGINEERING PRACTICES IN SUPPORT OF MEDICINE

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NON DESTRUCTIVE – NON INVASIVE METHOD FOR TESTING BONE STRUCTURAL INTEGRITY

NON DESTRUCTIVE TESTING

Used for Control of Structural Integrity

Fundamental for:

- proper function
- preventive damage diagnosis

BONE QUALITY MONITORING METHODS

Needed for monitoring of:

- metabolic bone diseases (osteoporosis, etc.)
- bone fracture healing

Osteoporosis evaluation

mainly based on measurements of
Bone Mineral Density (BMD)

EXISTING CONVENTIONAL TECHNIQUES

DEXA
QCT
pDEXA
RA (Radiographic absorptiometry)
QUS (Quantitative Ultrasound)
pQCT
RAMAN SPECTROSCOPY
HISTOMORPHOMETRY
BIOCHEMICAL MARKERS OF BONE
METABOLISM

All methods have Disadvantages related to:

Accuracy
Precision
Subjectivity
High Cost
Invasiveness
Portability

NEW METHOD BASED ON

DAMPING

(1784) Coulomb (***Memoir on Torsion***)
Described experiments where damping in torsional vibrations is due to material defects

DAMPING

Natural property of material and system

Takes values between (0-1)

Accounts for structure changes (porosity, cracks)

Expresses the defective percentage of the structure

Can be used as index of

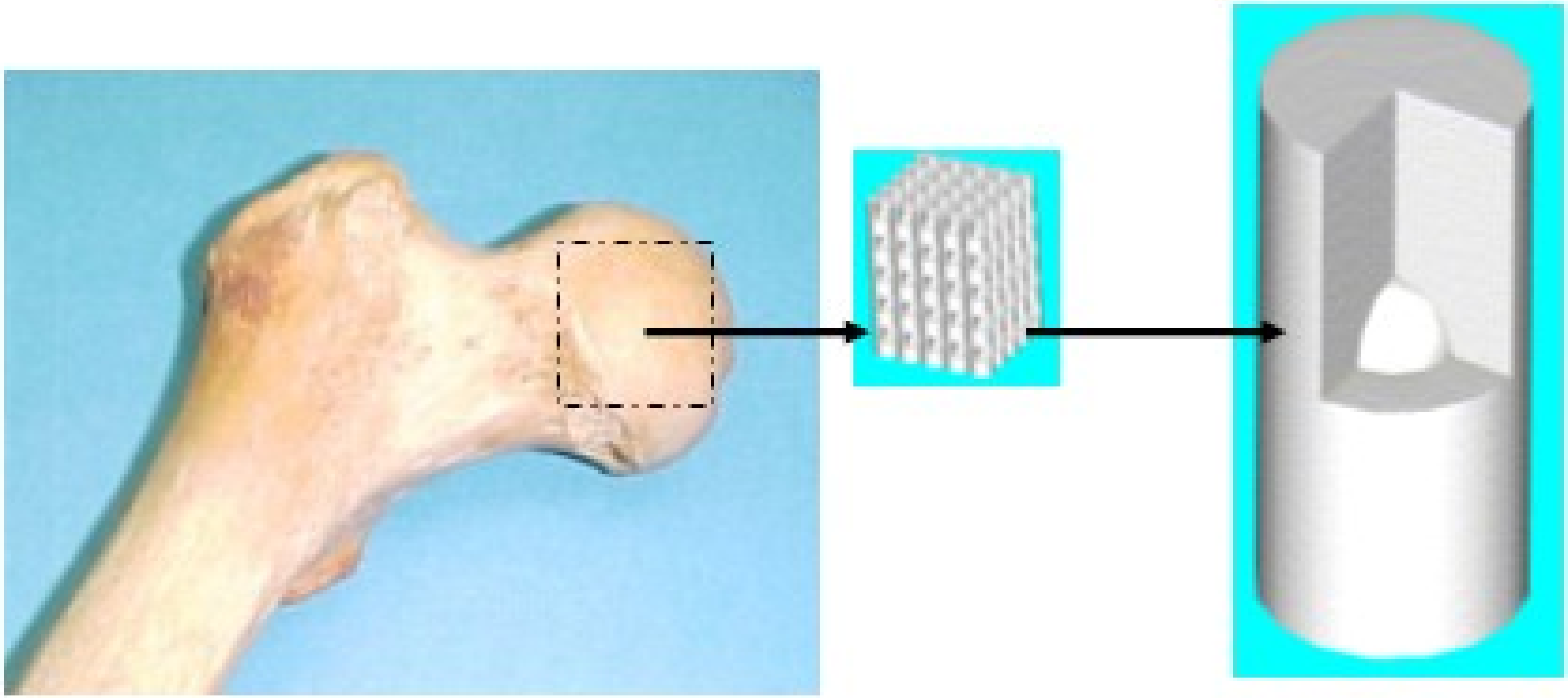
- structural integrity
- bone quality

ANALYTICAL PROCEDURE

Developed analytical - arithmetic model quantifying damping – porosity percentage

Damping change accounts for changes in porosity of the structure (bone)

Modeling of bone structure
Problem of material with cavities or inclusions

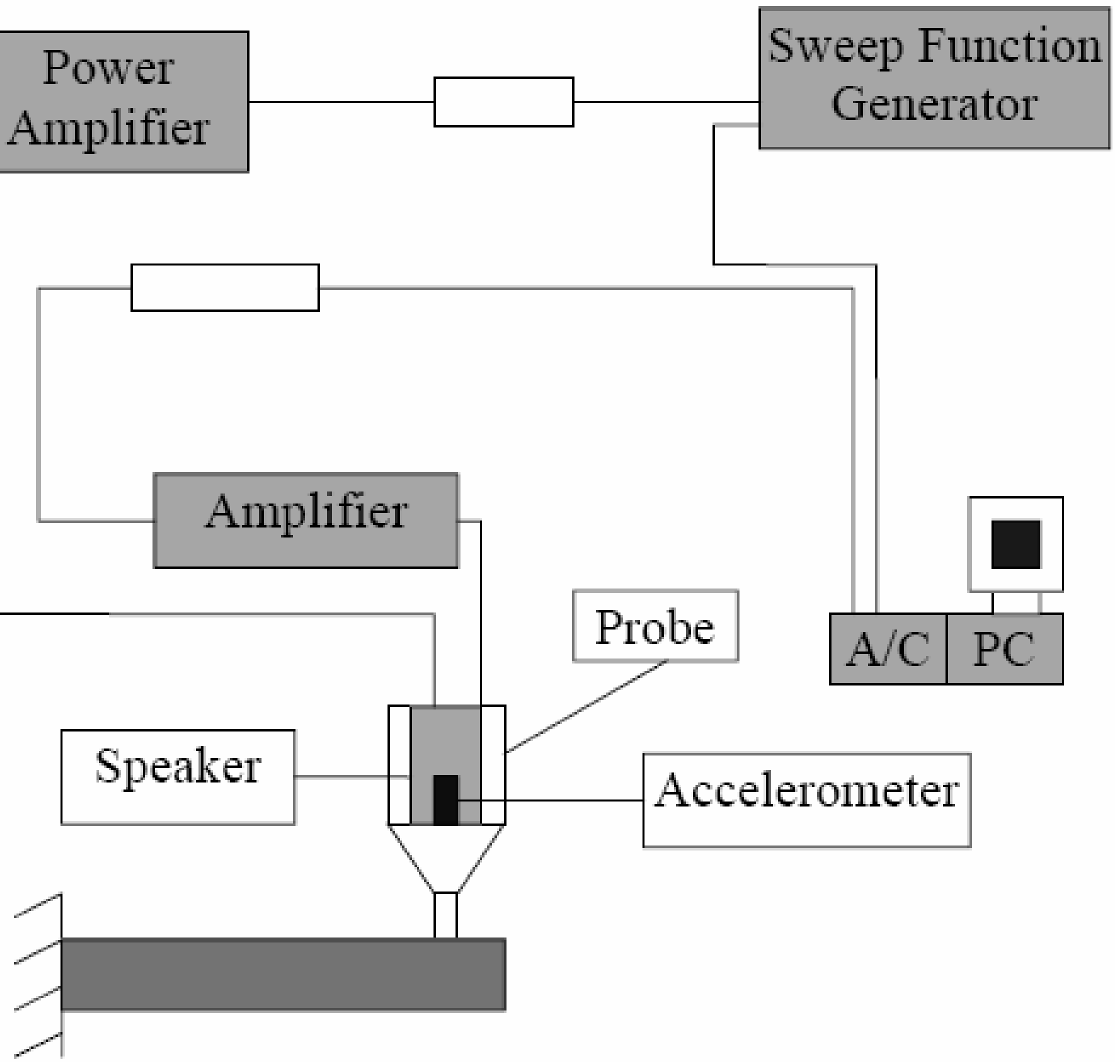


TECHNIQUES FOR DAMPING MEASUREMENT

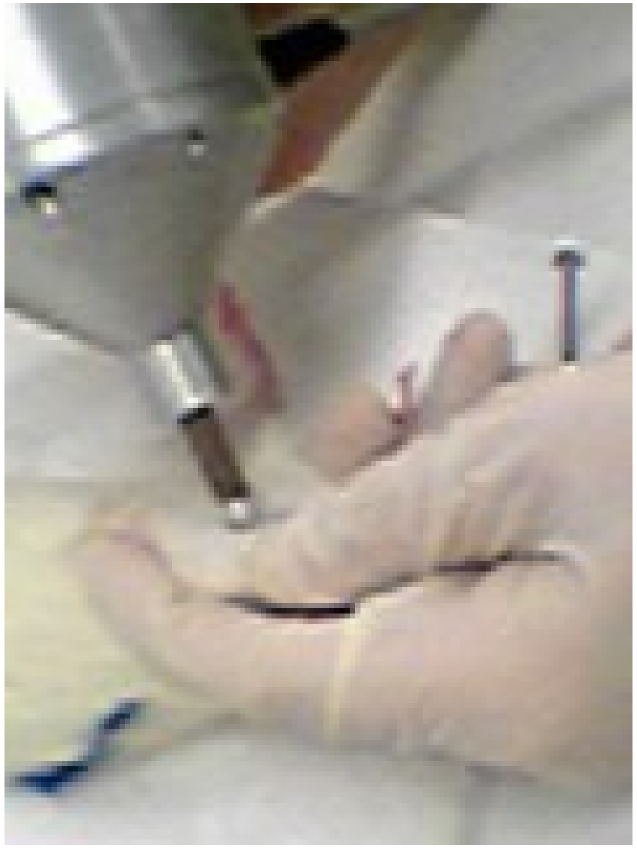
LOGARITHMIC DECREMENT

HALF POWER BANDWIDTH

Experimental Setup for Damping Measurement



Measurement of Damping

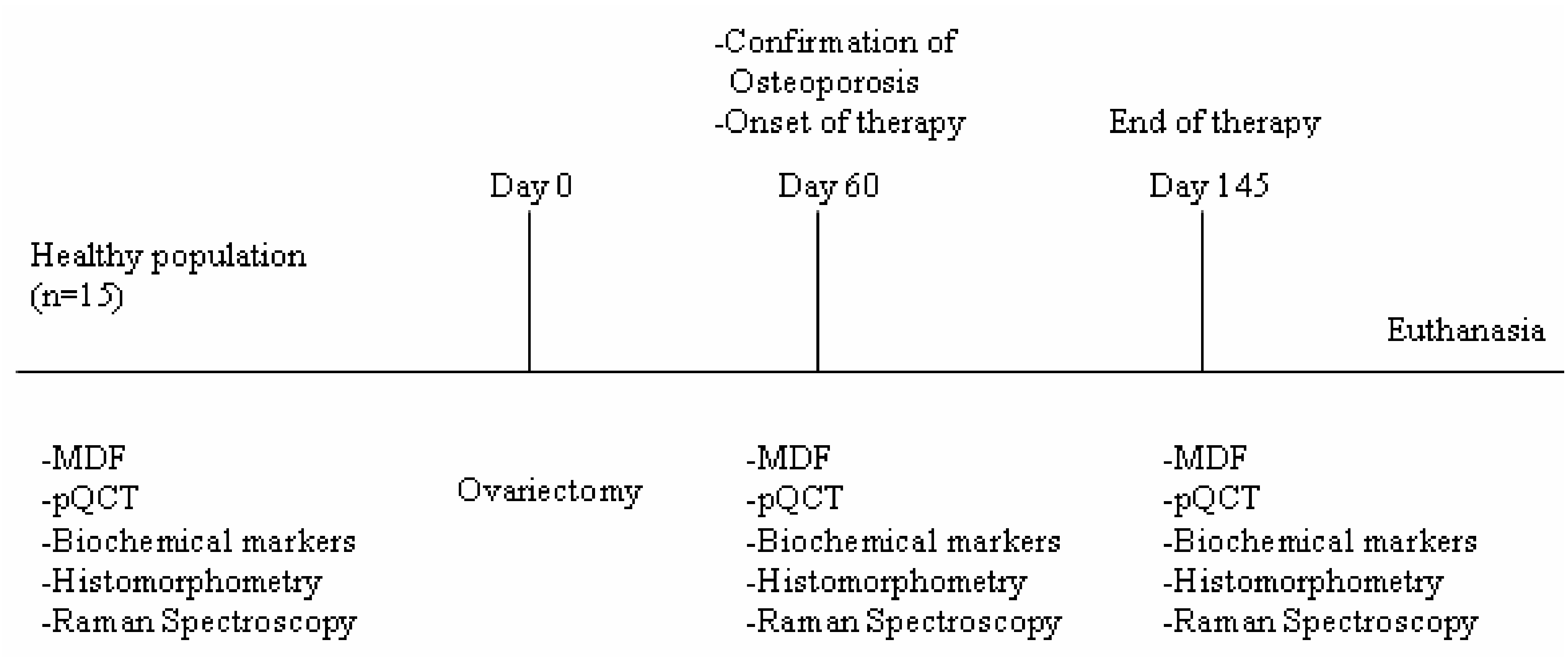


MEASUREMENTS PERFORMED ON RATS - WOMEN

Methods

DEXA
pQCT
Raman Spectroscopy
Histomorphometry
Biochemical markers
Modal Damping Factor (MDF)

Experimental Protocol on Rats



Bone densitometry with pQCT

Measurements in Women

Bone Density measurements with pQCT

50 women age 38-80 years
Testing on right tibia with pQCT

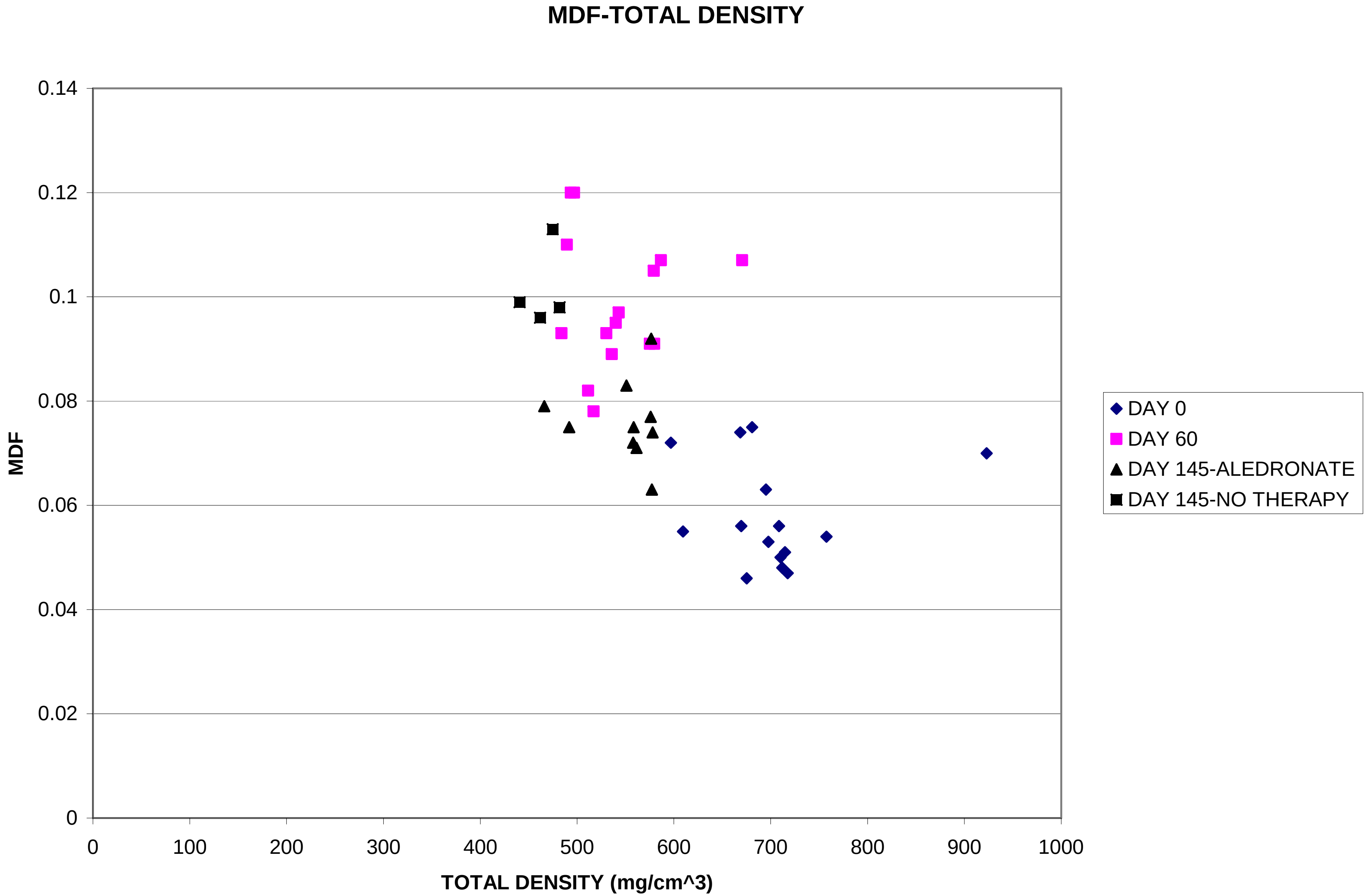
Transverse sweeping (4%, 14 %, 38%, 66% of tibiae length)

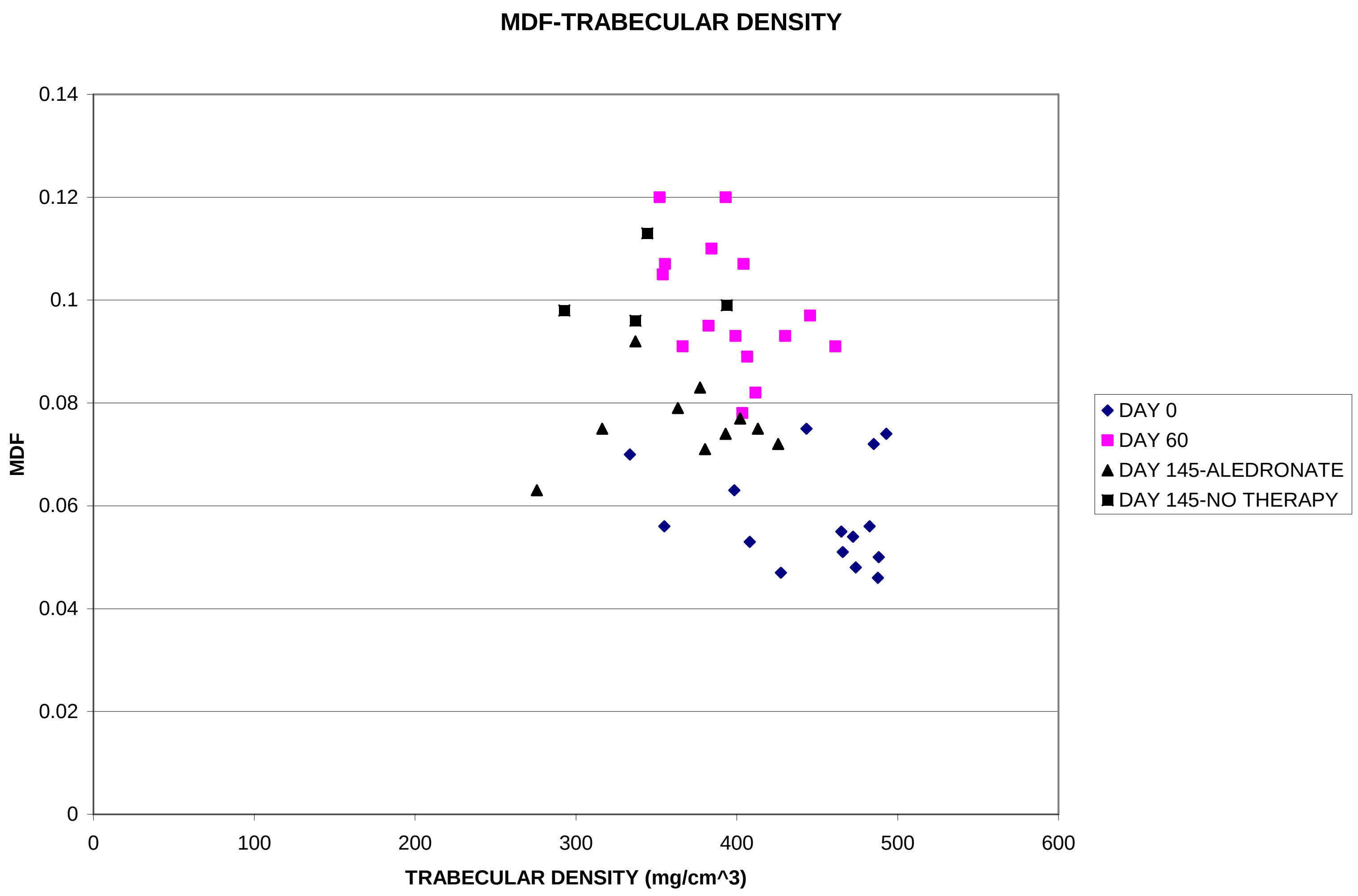
Section distant 4% from knee (for calculation of trabecular bone density)

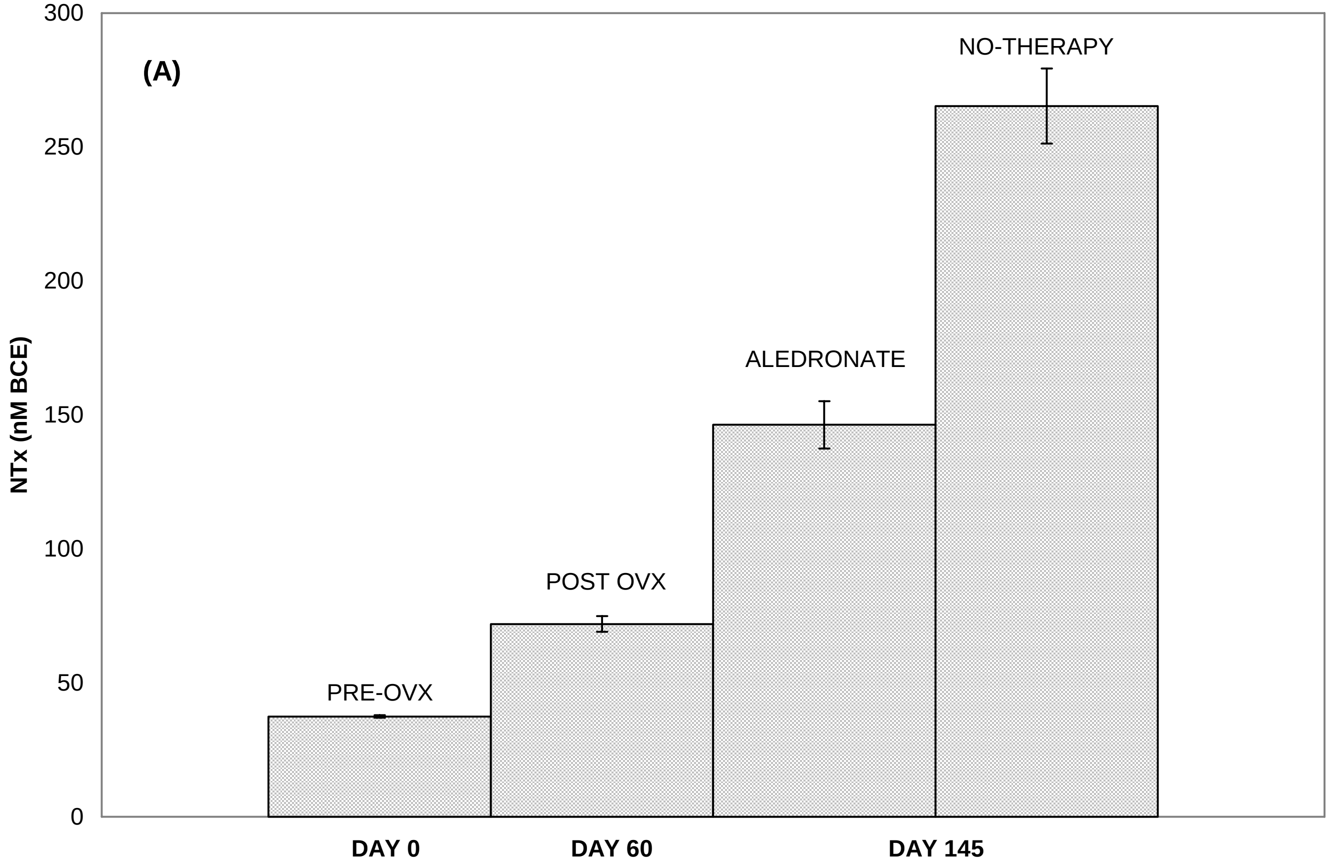
Sections distant 14% and 38% (for calculation of cortical bone density)

Section distant 66% of tibia length
Information for calculation of properties of the system bone-muscles

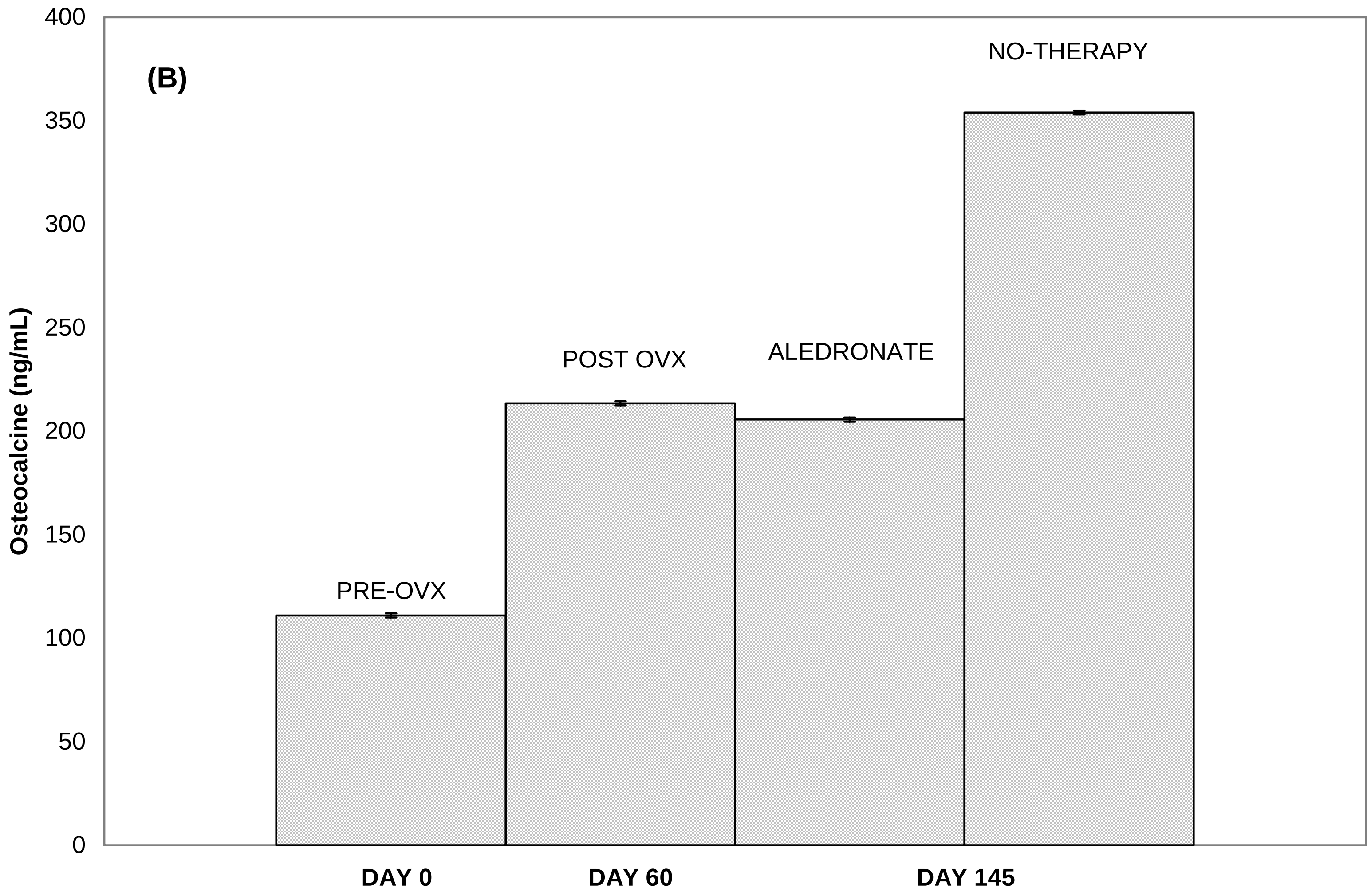
ΑΠΟΤΕΛΕΣΜΑΤΑ




MDF-TRABECULAR DENSITY
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
MDF
0
100
200
300
400
500
600
TRABECULAR DENSITY (mg/cm^3)
DAY 0
DAY 60
DAY 145-ALEDRONATE
DAY 145-NO THERAPY



NTx levels (all groups)



Osteocalcine levels (all groups)

CONCLUSIONS FROM MEASUREMENTS

Measurements on rats-women with:

- MDF
- Bone density (pQCT –DEXA)
- Biochemical Markers
- Raman Spectroscopy
- Histomorphometry

Methods selected because:

- are the most applied in clinical practice for osteoporosis diagnosis (pQCT, DEXA)
- as means for certification of bone metabolism architectural bone structure of animals (Biochemical Markers Raman Spectroscopy Histomorphometry)

Assessment of bone quality with MDF

Follows all changes with conventional methods

Sensitivity usually higher than conventional methods

MDF change between healthy-osteoporotic population = 66%

MDF change between
osteoporotic population - population after therapy = 18,8%

pQCT changes (same phases) 23 % and 1% respectively

Discrepancy supports improved sensitivity of MDF method

CONCLUSION

MDF - Modal Damping Factor

New
Non invasive
Short duration
Low cost
Easy in Use
Portable
More sensitive than all conventional methods
Objective

Method for assessment of Bone Quality

Monitoring of Damping
for the Assessment of Mandible Bone Quality

To facilitate decision about dental implant placement

Bone density: estimator of bone quality

Evaluation Methods for **Mandibular Bone Density**:

- Histomorphometry on biopsy samples
- Empiric topographic methods combining anthropometric data and simple panoramic radiographs
- Torque resistance measurements during implant insertion
- X-ray absorption methods

Golden standard for bone density measurements:

Histological and Morphometric measurement

Invasive and deleterious method

Small biopsy specimens are harvested from patient’s jaws immediately before implant placement

Empiric method

Advantages:

Easy and inexpensive method

Disadvantages:

Low Precision

High Subjectivity

Poor Comparability

Low Reliability

Cannot discriminate between osseous sites at the same individual

Result:

restricted capability of secure assessment of bone quality

Insertion torque measurements

are not a true bone density evaluator

Implant parameters

(design characteristics - insertion technique features)

co-influence actual measurements

X-ray absorption methods

Computed Tomography (CT)
Panoramic
Periapical
Cone beam CT
Dual Energy X-ray Absorptiometry (DEXA) (only for research purposes and only in the mandible)

Estimation of radiographic density allows for:
- site specific presurgical evaluation of bone density
- selection of the most suitable implant placement

Disadvantages:
- high irradiation dose
- accuracy affected by the fat content of the soft tissue
- discrimination between cortical and trabecular bone impossible due to superposition

Clinical - research interest in the preoperative planning of implant placement:

non-invasive

non-irradiating

non-destructive

more reliable

low cost

assessing bone structural integrity

assessing effect of therapeutic treatment non invasively

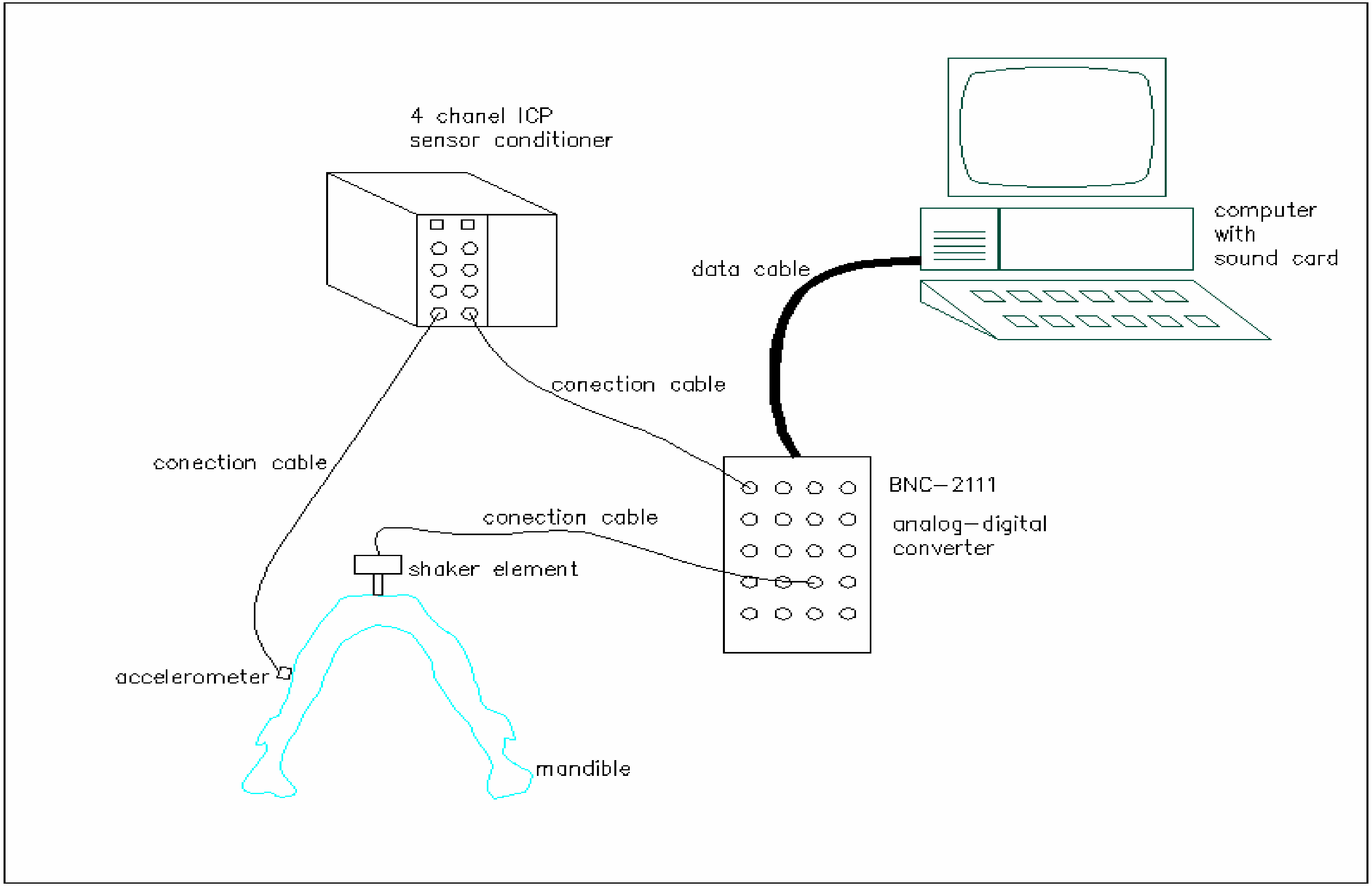
Development of non invasive technique for objective assessment of **mandible** bone quality

Technique is experimentally applied on cadaveric human mandibles

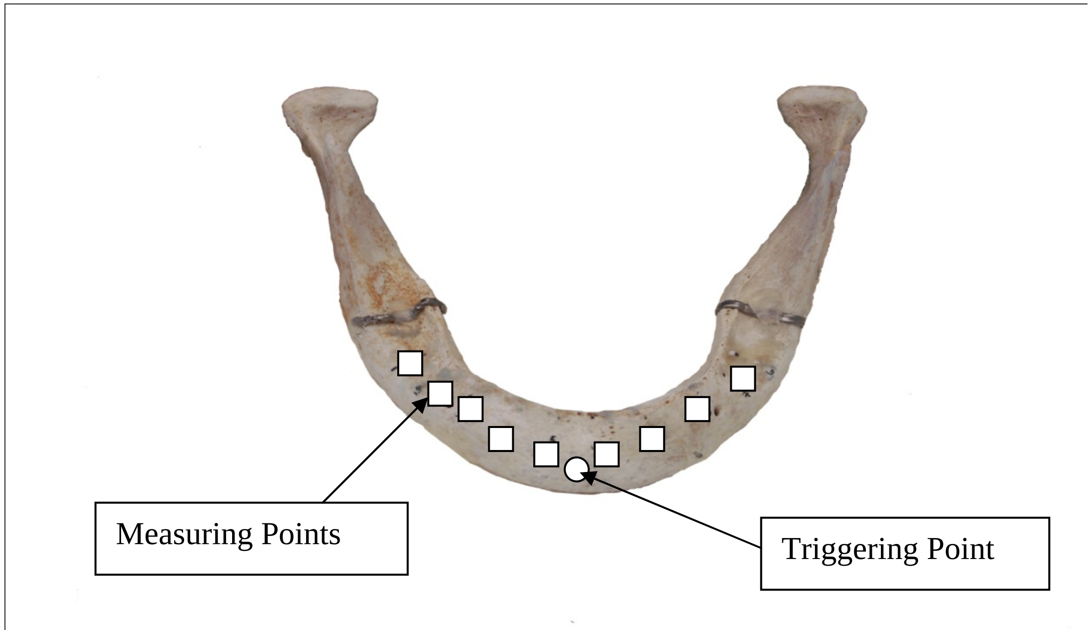
EXPERIMENTAL WORK

Ten cadaveric human mandibles, were used for in vitro measurements of mandible quality with two methods:

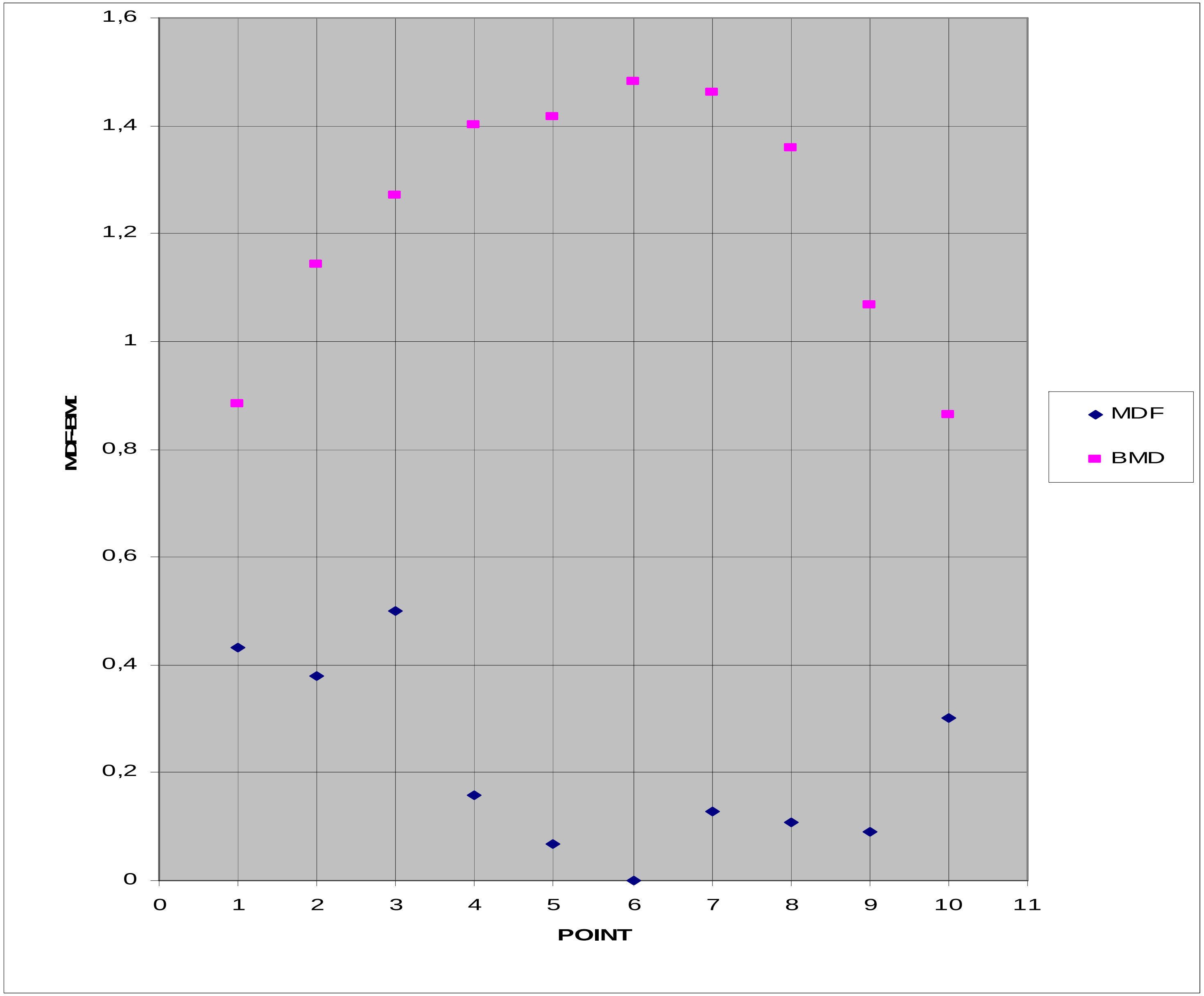
1. BMD (Bone Mineral Density) with DEXA
2. Modal Damping Factor (MDF)



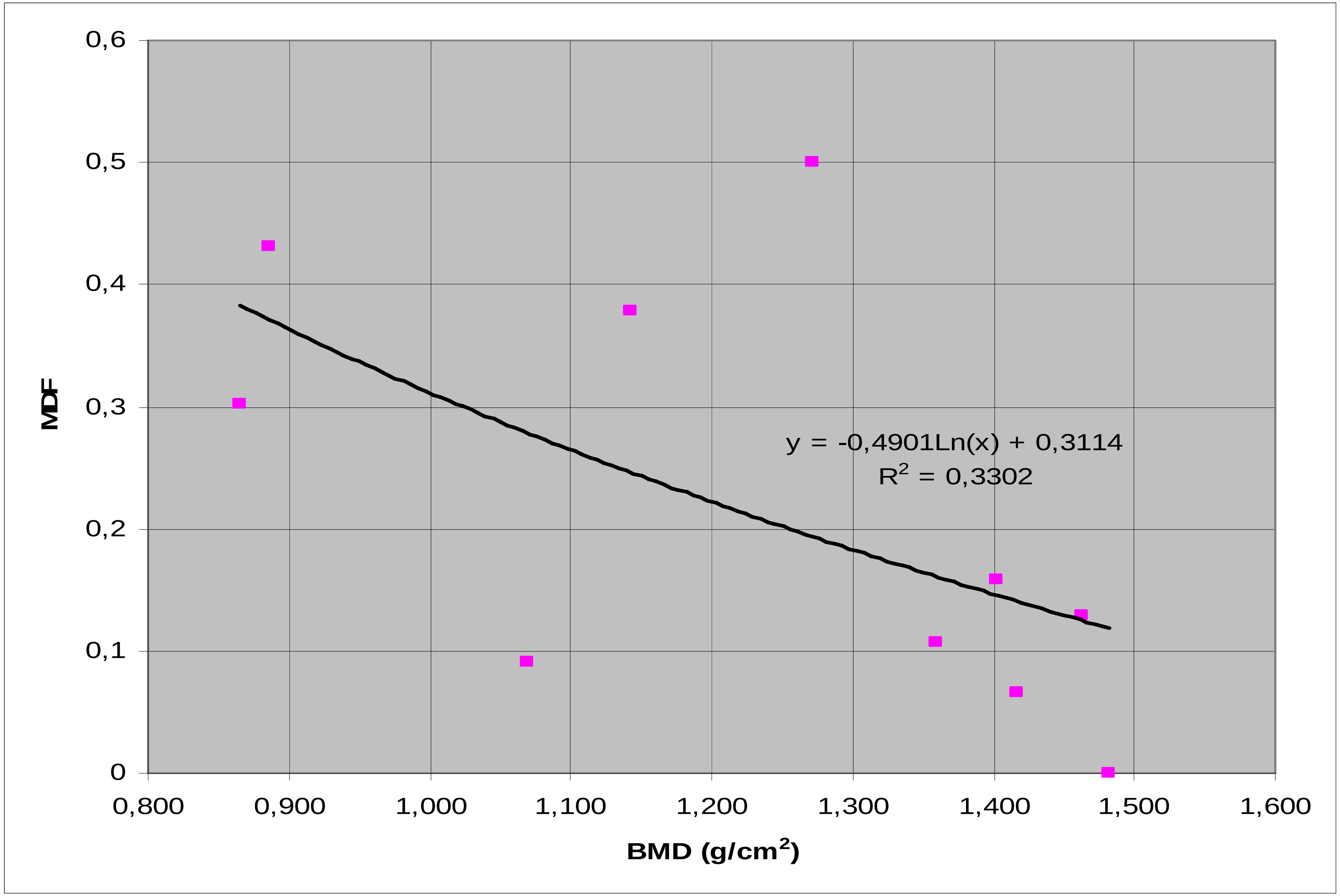
Experimental device for measurement of damping



Triggering and measuring points



Average of measured MDF - BMD vs anatomic site of measurement



MDF – BMD (all mandibles)

CONCLUSIONS

Change in damping depends on porosity
Increasing porosity leads to increase in damping
Damping - Porosity Positive Correlation

Comparison of measured MDF - DEXA reinforce the potential to build assessment tool for use in the process of placement of dental implant

METHODOLOGY FOR OBJECTIVE ASSESSEMENT OF MECHANICAL PROPERTIES OF PROSTATE GLAND

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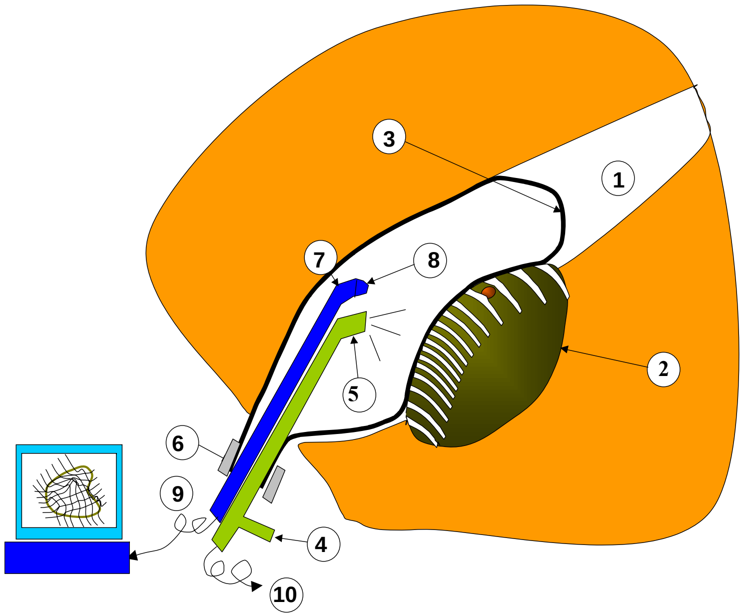
Designed and Developed:
simple – accurate - repetitive
method
for
geometric and stiffness mapping of prostate gland

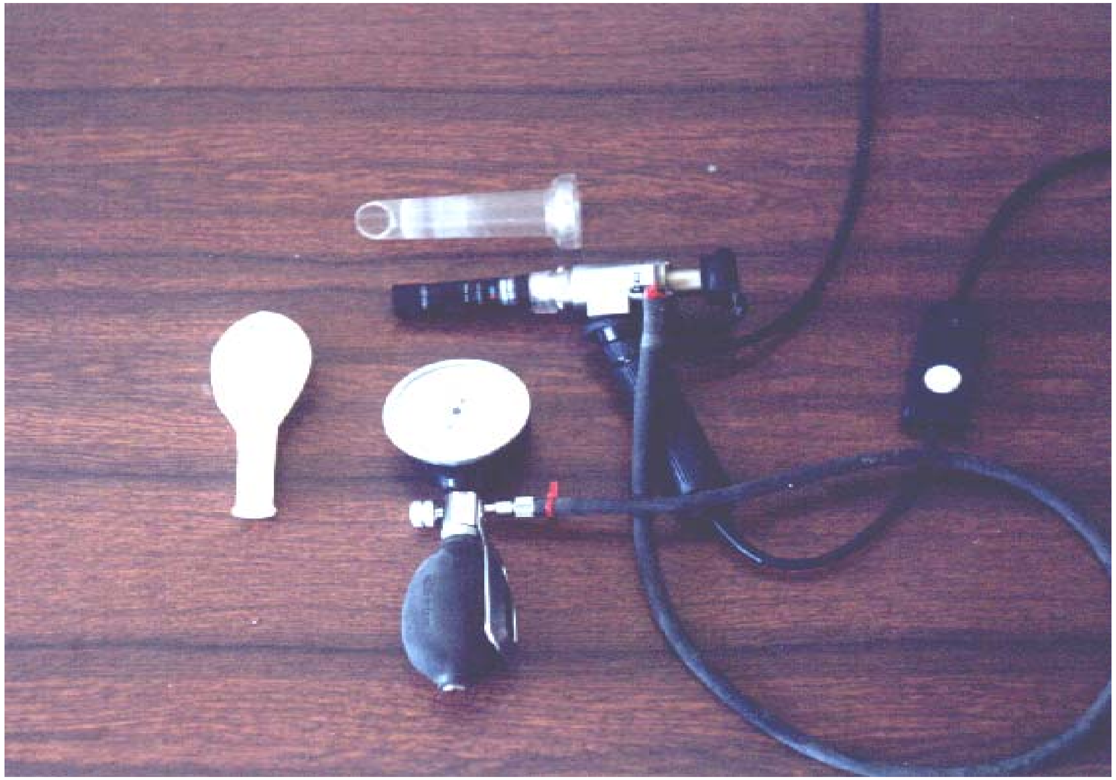
with the aid of compressed under control air
chamber and endoscope

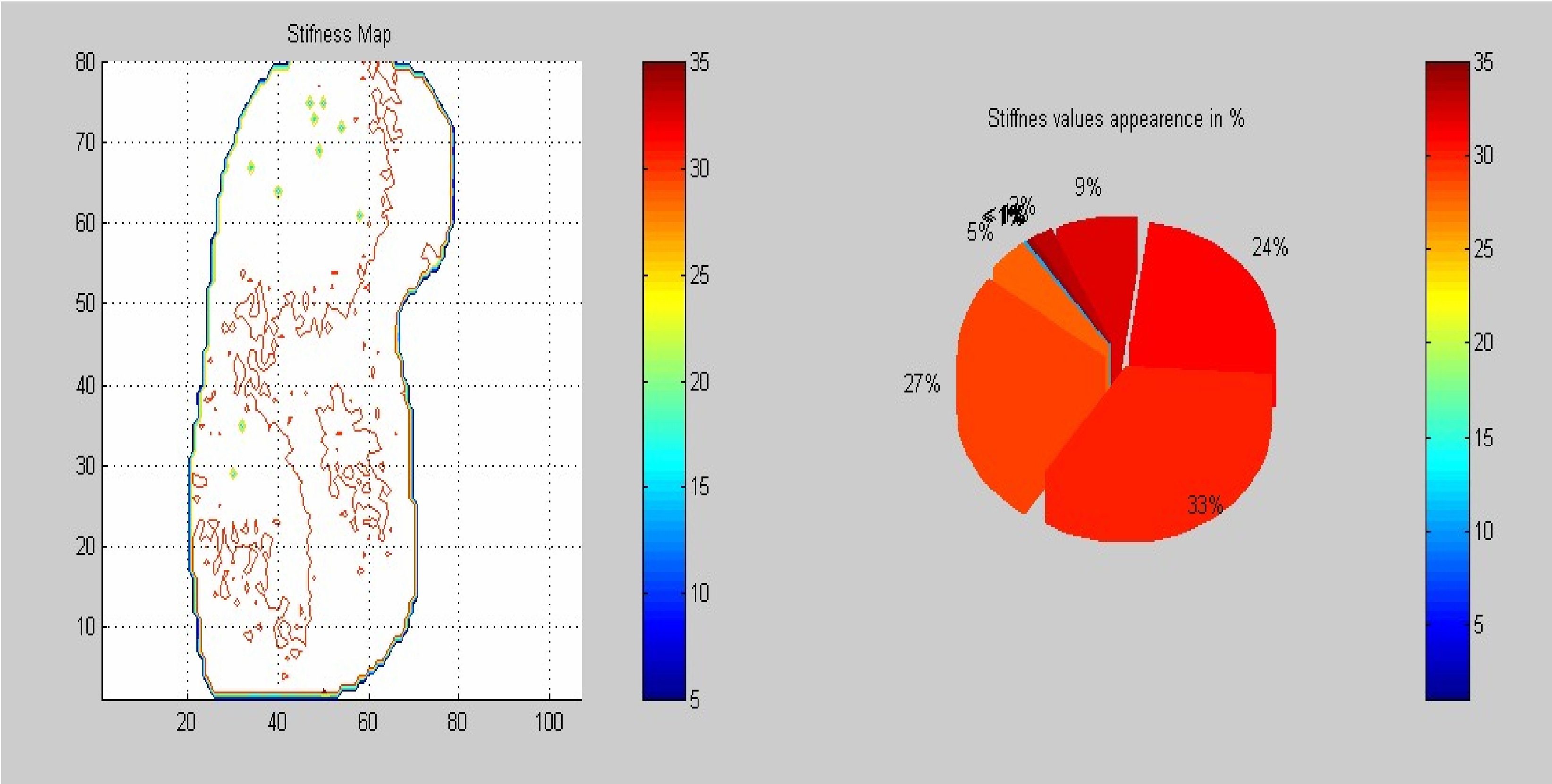
for the qualitative and quantitative assessment of
the mechanical properties of the prostate gland in
vivo

Functional idea of transducer



DEVICE





GEOMETRIC REPRESENTATION
CALCULATION AND DISTRIBUTION OF STIFFNESS (in vivo)

MEASUREMENTS - ASSESSMENT

Clinical study on humans in vivo:

Simultaneous measurements and assessment with:

Proposed method

Conventional methods (digital rectal examination, PSA, U/S/, biopsy)

In comparison to conventional methods the proposed method is:

Objective

Enables for creation of testing files for future comparisons

Conventional methods are subjective and non accurate

Non invasive due to minor disturb of the prostate

Extremely low cost in comparison to conventional methods (i.e. U/S, biopsy).

Biotargeting network ?

Osteoporosis machine (Panayotopoulos – Karamanos - Kontoyannis)

Next collaboration step: proposal submission in the frame of THALIS (Osteoporosis – Osteoarthritis) (Karamanos – Vynios – Kostopoulos)

Mandible machine (Kontoyannis)

Please think loudly in front of us

Most probably we'll come up with a solution to the needs of medicine!!!