Bone morphology characterization of Paget's disease and osteoporosis by artificial intelligence (AI)

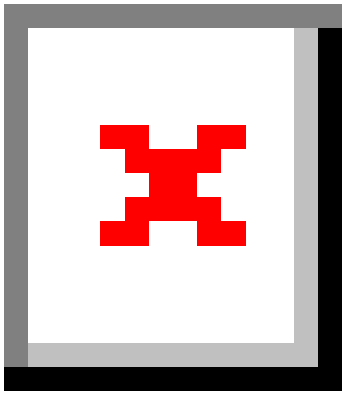
2023 Research Aid Awards (RAA)

Dr Jie Liu

liu.7050@osu.edu
O: 901-421-1463

FollowUp Form

Award Information



In an attempt to make things a little easier for the reviewer who will read this report, please consider these two questions before this is sent for review:

- *Is this an example of your very best work, in that it provides sufficient explanation and justification, and is something otherwise worthy of publication? (We do publish the Final Report on our website, so this does need to be complete and polished.)*
- *Does this Final Report provide the level of detail, etc. that you would expect, if you were the reviewer?*

Title of Project:*

Bone morphology characterization of Paget's disease and osteoporosis by artificial intelligence (AI)

Award Type

Research Aid Award (RAA)

Period of AAOF Support
July 1, 2023 athrough June 30, 2024

Institution
The Ohio State University

Names of principal advisor(s) / mentor(s), co-investigator(s) and consultant(s)
Ching-Chang Ko (Principal Advisor)

Amount of Funding
$5,801.50

Abstract
(add specific directions for each type here)

attached

Respond to the following questions:

Detailed results and inferences:*
If the work has been published, please attach a pdf of manuscript below by clicking "Upload a file".
OR
Use the text box below to describe in detail the results of your study. The intent is to share the knowledge you have generated with the AAOF and orthodontic community specifically and other who may benefit from your study. Table, Figures, Statistical Analysis, and interpretation of results should also be attached by clicking "Upload a file".

detailed results.pdf
attached

Were the original, specific aims of the proposal realized?*
Yes, the original specific aims were achieved
Aim 1: by using AI, significant difference in morphology will be found in PDB bones from OPTN-/- mice and osteoporosis bones from OVX mice
This aim was realized, however, since microCT image analysis and AI approach are ongoing, partial results of the project are presented in this report, based on PDB bones versus OVX bones.
Aim 2: by using Nanoindentation, significant difference in mechanical properties will be found in PDB bones from OPTN-/- mice and osteoporosis bones from OVX mice

This aim was realized. All femurs were collected and ready for Nanoindentation test.

Were the results published?*
No

Have the results of this proposal been presented?*
Yes

To what extent have you used, or how do you intend to use, AAOF funding to further your career?*
With the generous support of the AAOF Research Aid Award, I was able to develop my research project exploring the bone morphology characterization of Paget's disease and osteoporosis by utilization of artificial intelligence. Receiving the AAOF Charles J Burstone Award for this research project has encouraged and reinforced my career goal in becoming a clinician- scientist in academia.

Accounting: Were there any leftover funds?
$0.00

Not Published

Are there plans to publish? If not, why not?*
This work has not yet been published. There are plans to publish and the manuscript is currently being prepared. AAOF support will be acknowledged.

Presented

Please list titles, author or co-authors of these presentation/s, year and locations:*
Title: Bone Morphology Characterization of Paget's disease and Osteoporosis by Artificial Intelligence (AI)
Authors: Jie Liu, Tai-Hsien Wu, Yi-Chu Wu, Yunchan Daniel Lim, Do-Gyoon Kim, Ching-Chang Ko
Location: AAO Annual Session 2024- New Orleans, LA (William R. Proffit Resident Scholar Award).

Comment: *The AAOF congratulates you on the execution and completion of this work. We encourage your application for future AAOF Funding and look forward to witnessing the advancement of our specialty through scholars like you.*

Was AAOF support acknowledged?

If so, please describe:

Yes, a written statement thanking the AAOF for their support of the project was included on the poster

Internal Review

Reviewer comments

Reviewer Status*

Approved

File Attachment Summary

Applicant File Uploads

- detailed results.pdf

Detailed results and inferences:*

Following the IACUC approval from the Ohio State University, C57BL/6 mice were used as following:

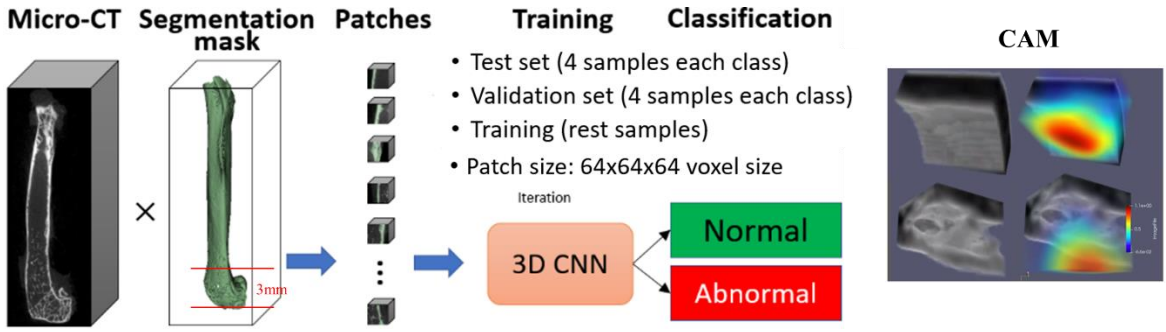
- Group 1: Paget's disease of bone (PDB), OPTN gene knocknot (KO), C57BL/6 mice, aged 20-24 months (Male and Female, n=33).
- Group 2: wild type (old WT) aged 20-24 months, C57BL/6 mice (Male and Female, n=25)
- Group 3: Osteoporosis (OVX), C57BL/6 mice, 3 months age + 8wks post ovariectomy (Female, n=15)
- Group 4: wild type (young WT) aged 4-5 months, C57BL/6 mice (Female, n=20)

After euthanize, one femur was collected, followed by scanning using micro-computed tomography (μCT50, Scanco Medical AG, Switzerland) with 10×10×10 μm^3 voxel size. The other femur from each animal was prepared for Nanoindentation.

Since microCT image analysis and AI test are ongoing, following is partial results of the project, based on PDB bones versus OVX bones

1) AI test

Methods: after micro-CT scanning, bone voxels from groups 1 and 3 were segmented from non-bone voxels using a heuristic algorithm. All μCT scans of KO and OVX were utilized to train our 17-layer 3D convolutional neural network (3D-CNN) algorithm to identify PDB bones versus OVX bones, as described in Fig. 1.



Results: as showed in table 1, 3D CNN can identify PDB bones and OVX bones with 71% and 75% accuracy, based on valid patch contains 10% and 40% positive voxels, respectively.

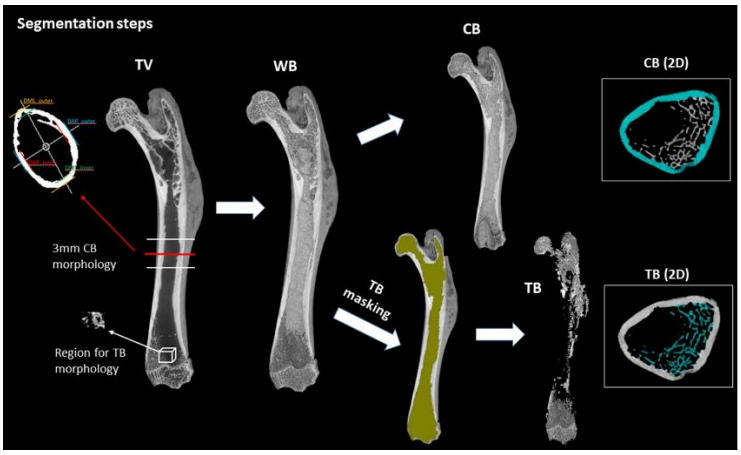
KO vs OVX trial1	Valid patch contains 10% positive voxels
# of KO patches	311
# of OVX patches	338
SEN (OVX as positive)	0.93
SPE	0.46
ACC	0.71

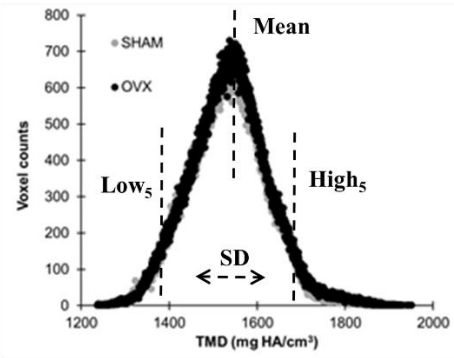
KO vs OVX trial1	Valid patch contains 40% positive voxels
# of KO patches	31
# of OVX patches	40
SEN (OVX as positive)	1.0
SPE	0.42
ACC	0.75

KO: OPTN-/- (PDB); **OVX**: osteoporosis; **SEN**: sensitivity; **SPE**: specificity; **ACC**: accuracy

2) Bone properties characterization by μCT scans

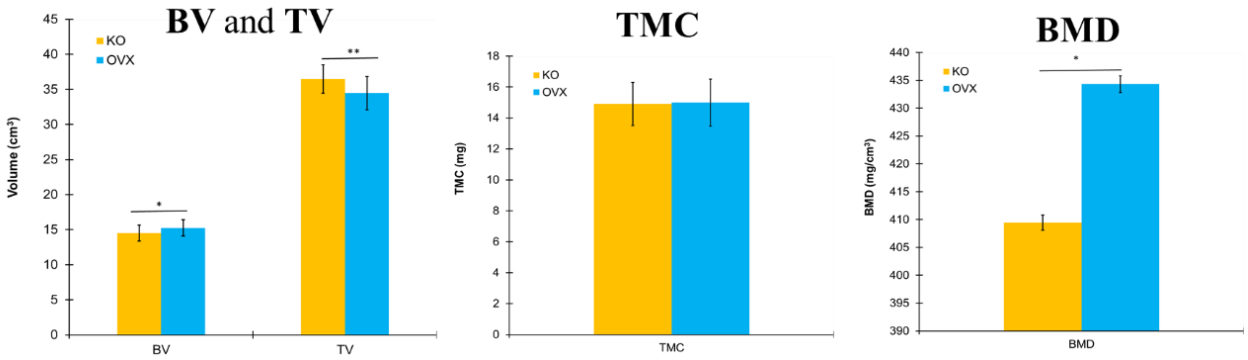
Methods: as showed in Fig. 2, after segmentation of cortical bone and trabecular bone, μCT tomography provided bone volumetric, mineral density, and morphological parameters of cortical bone (CB) and trabecular bone (TB).



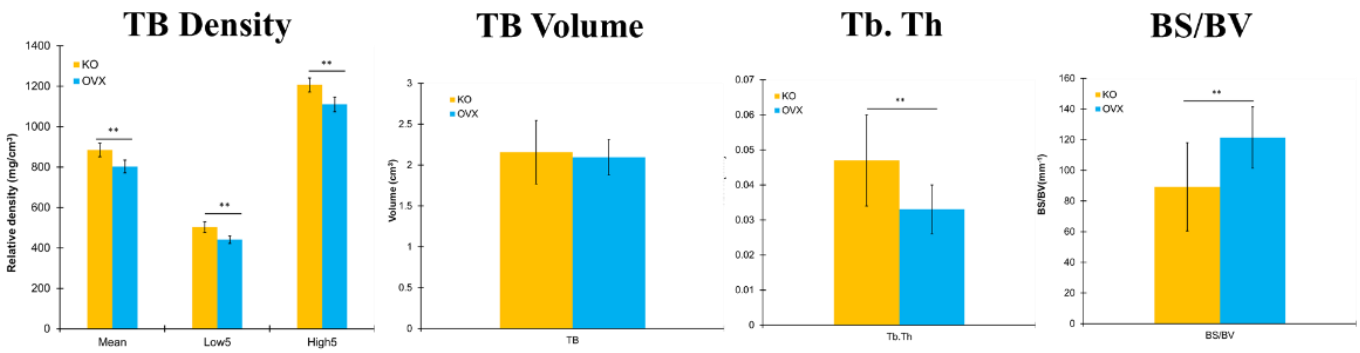


Results:

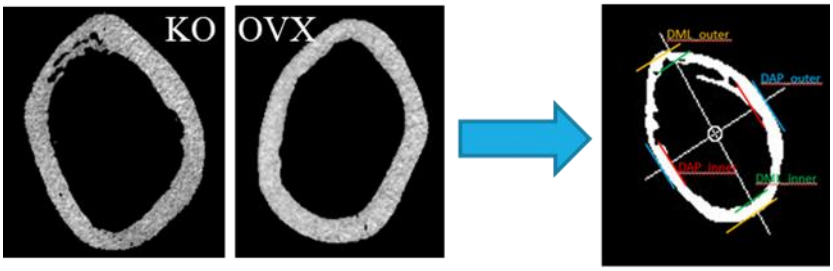
- Whole bone analysis: compared with OVX bones, PDB bones had significantly decreased BV and BMD. But the TV significantly increased in PDB bones.

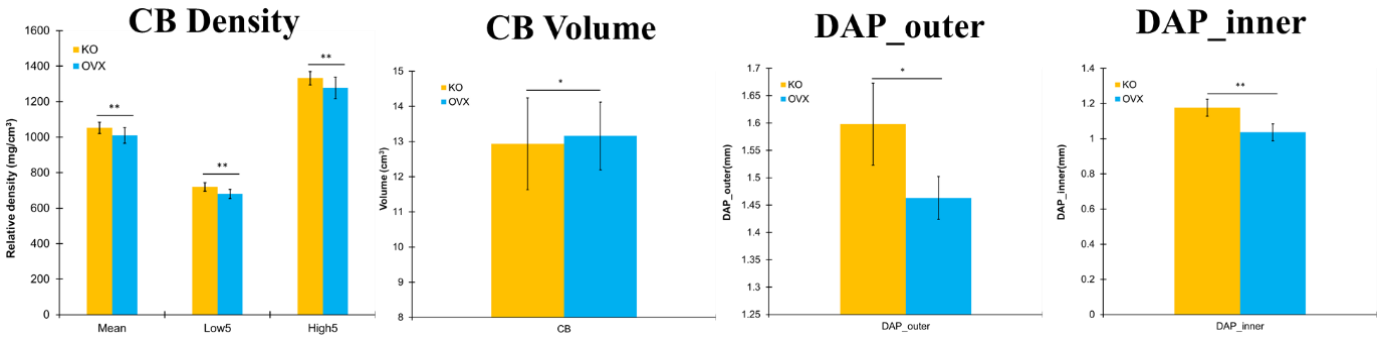


- Trabecular bone analysis and morphology: PDB bones had significantly increased values of mean, Low5 and high5. Morphologically, PDB had increased trabecular bone thickness (Tb.Th) but decreased BS/BV.



- Cortical bone analysis and morphology: PDB bones had significantly increased values of mean, Low5 and high5. Morphologically, PDB had increased DAP_outer and DAP_inner.





In summary, with the advent of AI, new findings in bone morphology/architecture, which cannot be detected by regular µCT image reading, are observed. It may serve as a novel tool to distinguish and diagnose PDB and osteoporosis. Bone volumetric, mineral density and morphological parameters are significant different between PDB and osteoporosis bones.