



Mind Your T's and Z's: Discovery and Correction of Dual Energy X-ray Absorptiometry Cross-Calibration Bias

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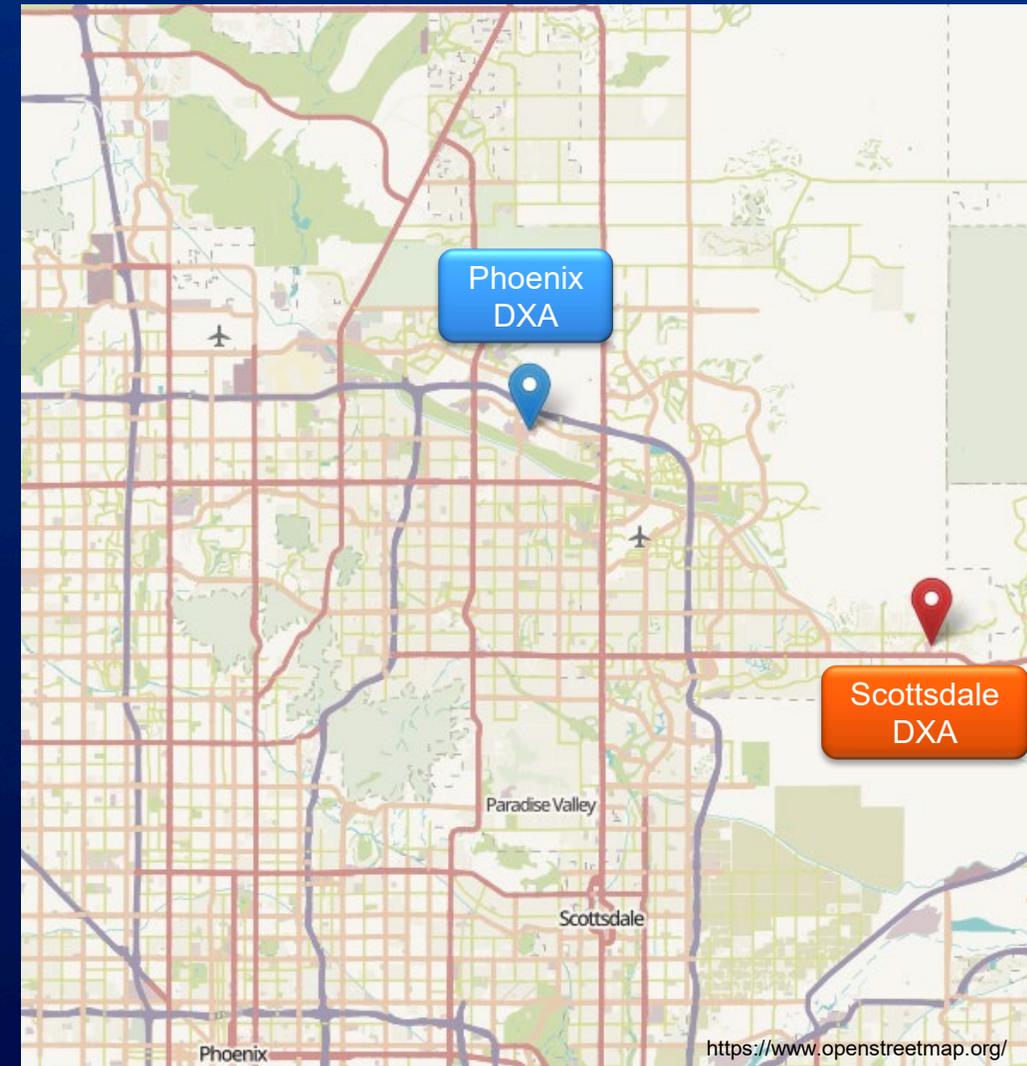
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Background

- Mayo Clinic Arizona operates two dual energy x-ray absorptiometry (DXA) units.
 - Units are the same make and model.
- DXA measures Bone Mineral Density (BMD) which is used to diagnose and monitor osteoporosis. Higher BMD is generally healthier bone.
- Endocrinology expressed concern that **DXA was reporting BMD gains from therapy that seemed too high.**

13-mile drive between sites



Confirm the Clinical Suspicion

- For each of 25 patients from each Mayo Clinic Site (Arizona, Florida, and Rochester)
 - Spine, R Hip, & L Hip BMD measurements were collected
 - % change of BMD from three most recent BMD measurements was calculated
- Patient exams were at various time intervals
 - Data was normalized to % change in two years
- Unpaired Student's *t*-test to identify significant differences between sites



Example calculation

DXA Exam 1



5% BMD change normalized to two years



DXA Exam 2 (2.3 years later)



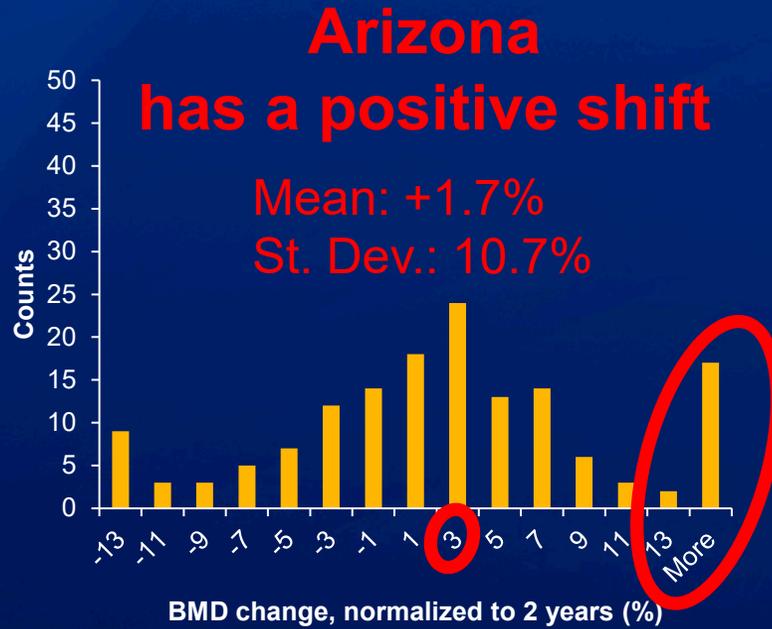
4% BMD change normalized to two years



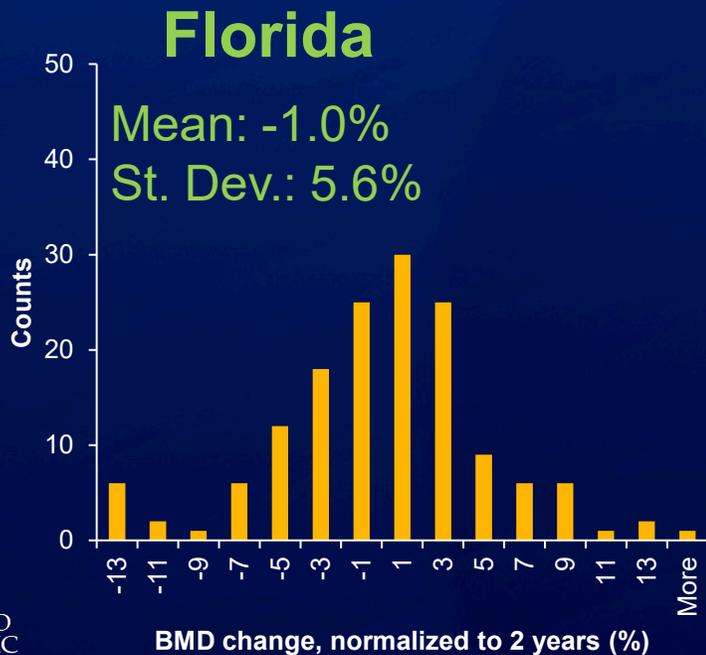
DXA Exam 3 (1.7 years later)

Clinical suspicion confirmed: Arizona had much higher BMD gains

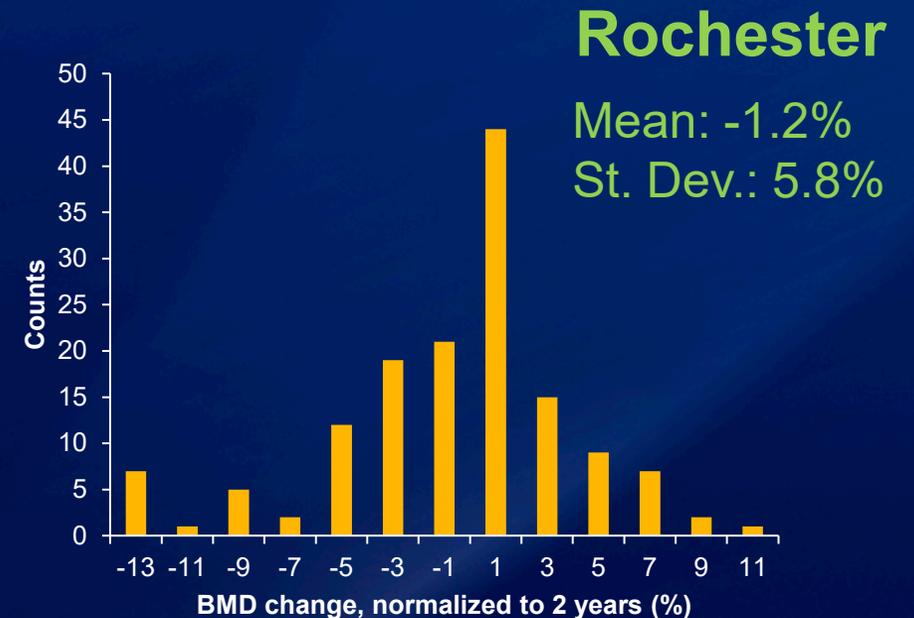
Significant
 $p = 0.00583$



Significant
 $p = 0.00320$



$p = 0.746$
Not Significant



Investigation 1: Precision assessment of least significant change (LSC)

- LSC is the test-retest precision of measurement in the clinical environment.
- It accounts for variations due to technologist and patient positioning.
- LSC limits from International Society of Clinical Densitometry (ISCD) [1]
 - Spine: < 5.3%
 - Femoral Neck: < 6.9%

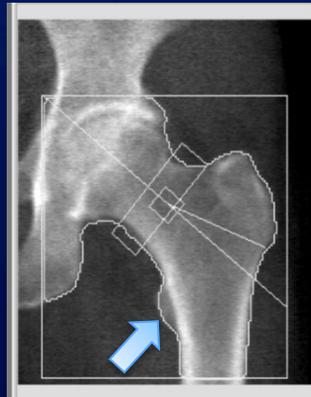
LSC Averages	Unit 1 LSC	Unit 2 LSC
Spine	4.9%	2.1%
Right Femoral Neck	6.3%	2.5%
Left Femoral Neck	5.6%	5.3%

Result 1: Technologist variability likely not the cause

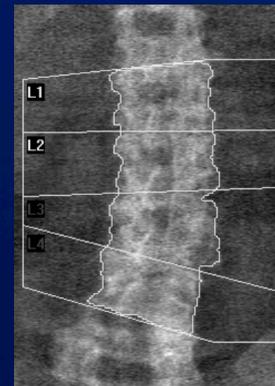
Investigation 2: Poor positioning

- Spine: Should be straight vertical and not too high or too low. [2]
- Hip: Should not crop the femoral head nor reveal the lesser trochanter. [2]
- Similar errors found at all three Mayo Clinic sites.
- Suboptimal positioning is frequently the result of patient flexibility limitations.
 - Techs repeat bad positioning from earlier measurements to ensure consistency.

Lesser Trochanter



Bent Spine



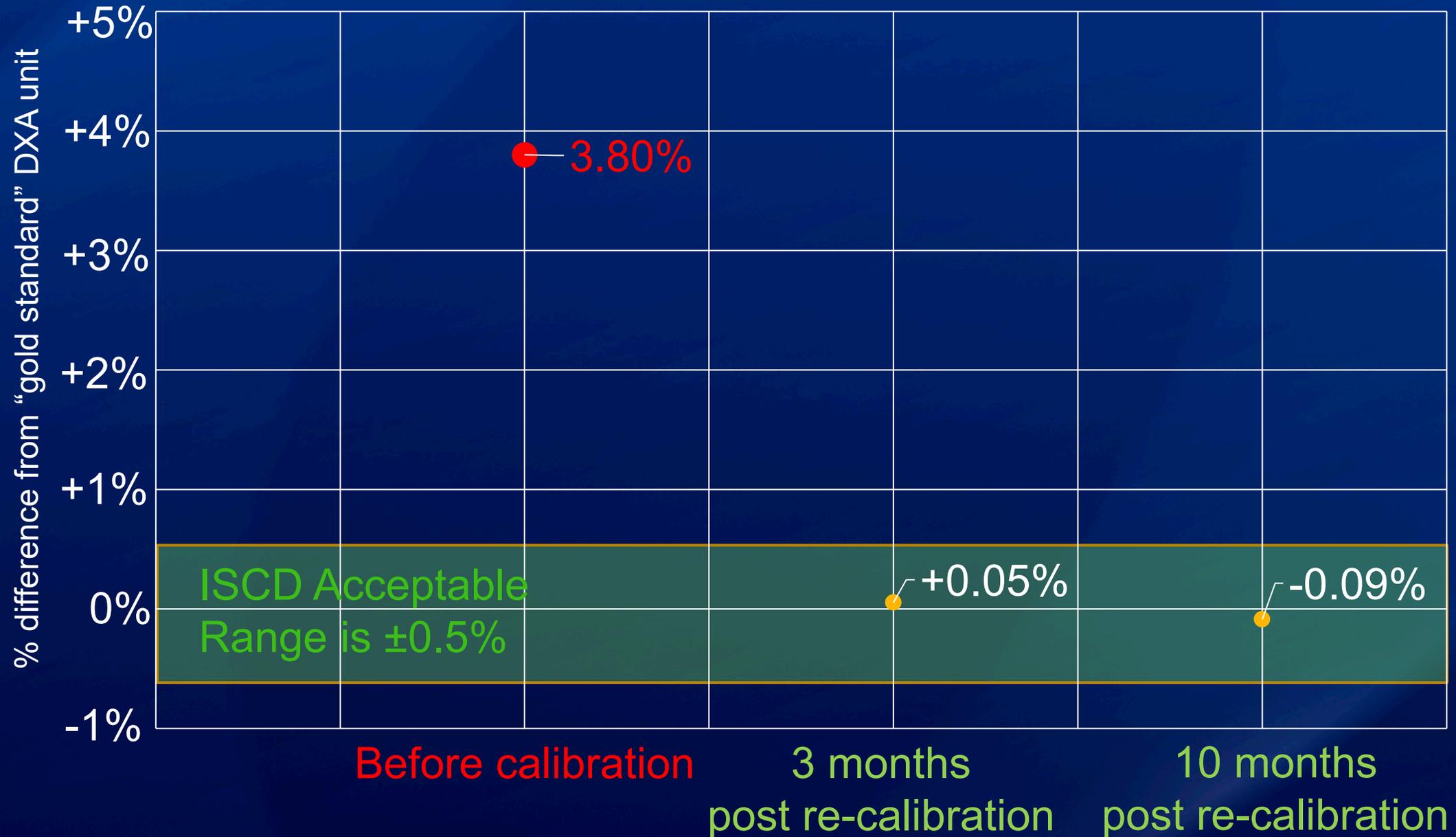
Result 2: Poor positioning likely not the cause

Investigation 3: Check cross-calibration

- Vendor found no maintenance issues and reported machines were cross-calibrated at installation.
- ISCD guidelines recommend $< 0.5\%$ BMD difference using the same vendor daily QC phantom on both machines over 20 consecutive days [1].
 - Physical distance prevented us from the phantom every day, so the QC phantom was measured 10 times on each unit instead.
- One DXA reported BMD that was 3.8% higher than the other.
- A vendor recalibration nearly eliminated the difference.
 - We chose one unit as the “gold standard” for all future units to be calibrated to.
 - Follow-up cross-calibration measurements confirmed a durable improvement.

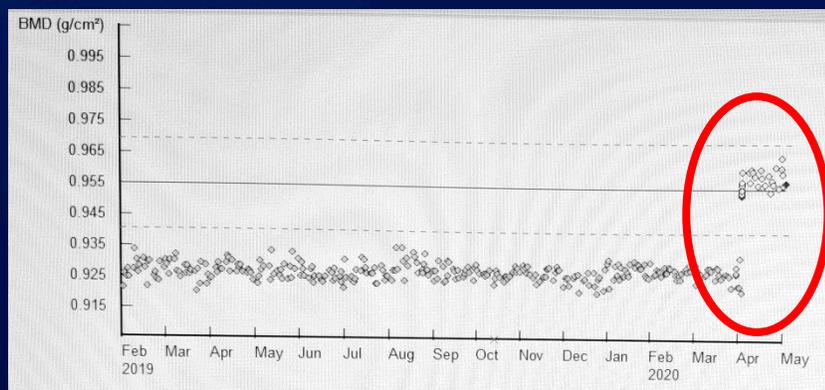
Result 3: Cross-calibration was the cause & recalibration solved it

Initial and follow-up measurements of cross-calibration

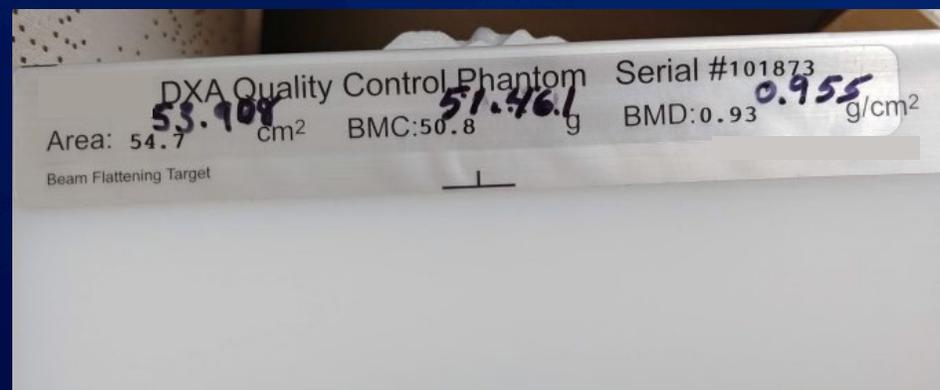


Implications and Lessons Learned

- Setting one machine as the new gold standard device meant that older scans from the other device were no longer reliable.
 - Physician and Allied Health communication campaign was implemented to ignore those old measurements.
 - Patients who had baseline measurements from recalibrated scanner received new baseline scans by designating a new 'good' scan for percent change calculations.
- Accepted values for the QC phantom associated with the other scanner were relabeled based on values given by the gold-standard DXA scanner.
- A cross-calibration check became part of our acceptance and annual QC.



Recalibration impact on BMD measurement



Relabeling of phantom based on calibration

Final Remarks

- Clinical suspicion led to an investigation of DXA units.
- Several possible sources of error were investigated.
- Patients may be scheduled at either of our DXA scanners, requiring the scanners to be cross-calibrated to give accurate results.
- Despite vendor documentation of cross-calibration, it was found that cross-calibration was insufficient.
 - Later investigation pointed to the problem being the installation and removal of several scanners as well as imprecise language regarding which scanners were cross-calibrated.
- Cross-calibration checks should be part of acceptance and annual QC.



We would like to thank all our excellent DXA Technologists for their hard work and help
We would also like to thank Chuck Harms, Mayo Clinic Engineering, for his assistance
troubleshooting this problem and collecting crucial data.