Bone Ninja App: User Guide

Introduction

Bone Ninja is an educational tool that helps surgeons learn how to analyze long bone deformities that may result from birth defects, developmental problems, traumatic injuries, or malunited fractures. To correct a deformity, one must first characterize the type of deformity and then appropriately plan a corrective strategy. Bone Ninja comes preloaded with case examples (normal and deformed bones) to use for practice. Each case example is accompanied by a recommended solution so that the student can receive feedback. We feel that this case-based approach will assist clinicians in learning bone deformity analysis and correction.

Please watch our YouTube Tutorials for step-by-step explanations of the tools and how to use them:
Bone Ninja App Tutorial:
https://www.limblength.org/about-us/social-media-news-videos/videos/bone-ninja-app-tutorial-version-4-0/
Introduction Part 1: http://youtu.be/tGlJwKlM1t4
Introduction Part 2: http://youtu.be/C_pkVb1V5L4

It is said that the best apps require no manual or instruction. Perhaps that is true, but the more complex a computer program, the more time one needs to spend to learn how to use it. For example, you can spend $50 a month on software such as Photoshop, but unless you invest the time to learn how to use it, it will not be worth the money you paid. Likewise, with Bone Ninja, you must invest a certain amount of time to become facile with the program and achieve the benefits.

Background

In the past, surgeons have learned bone deformity correction with traditional tools (e.g., paper, pencil, goniometer) on hard copy x-rays. In the current digital era, the majority of radiographs are images on a computer screen. Surgeons can now use digital tools to measure deformities and plan surgical corrections. Bone Ninja's teaching metaphors are based on the types of line and angle tools commonly found in Picture Archiving and Communication Systems (PACS), supplemented with additional sophisticated "paper doll" cutting tools.

The foundation of deformity analysis may be found in the textbook *Principles of Deformity Correction* (Springer 2002) by Dror Paley with editorial assistance from John E. Herzenberg. Based on this classic work, Bone Ninja helps to push the envelope further with new planning approaches and by embracing the digital technology available on the iPad.

The primary authors of this app (Dr. Shawn Standard and Dr. John Herzenberg) have a combined experience of more than 50 years working in the fields of deformity analysis and corrective surgery. This experience includes teaching an annual seminar, the Baltimore Limb Deformity Course (www.DeformityCourse.com). We developed this app to supplement this course and look forward to feedback from attendees and other users.

This app will be updated periodically by adding more case examples, explanations, and tools. The moniker "Bone Ninja" is intentionally whimsical and reflects our philosophy of teaching as "infotainment." Enjoy!

Main Menu Screen
Main Menu Toolbar (located at the top of the Main Menu page)

Downloading the Current Lessons & Resources

After you purchase Bone Ninja, the app will download and will include several case examples. The remaining cases can be downloaded by pressing the "Download Current Lessons & Resources" button on the Main Menu toolbar (Internet connection required). We update our case examples periodically, so press this button regularly to download the most recent case examples and solutions.

Menu Viewing Options

On the main menu page, the cases may be displayed either in a list or in a graphic format. Choose the format that you prefer by selecting one of the two buttons on the top right of the Main Menu toolbar.

Loading a Supplied Case

To load a case from the Main Menu, tap on it.

Loading Your Own Case into Bone Ninja

There are three ways to upload your own case examples into Bone Ninja:

1. E-mail yourself a JPEG of the radiograph and download that file into your Photo Library on your iPad. Then press "Add Photo" in the top left of Bone Ninja's Main Menu toolbar. Your image should be in the Photo Stream folder.
2. Use your iPad camera to take a photo of your computer screen or hard copy image. Press "Add Photo" in the top left of Bone Ninja's Main Menu toolbar. Your image should be in the Camera Roll folder.
3. If you have previously worked on cases in Bone Ninja and have saved them to your iPad, you can also open these cases in Bone Ninja. Press "Add Photo" in the top left of the Main Menu toolbar. Your image should be in the Bone Ninja Photo Album. Note: You will not be able to modify the elements (lines, cut outs) on a previously saved Bone Ninja image. You can, however, use Bone Ninja to make new lines and new cut outs on a saved image.

Deformity Correction Screen
Menu Bar (at the top of the Deformity Correction screen)
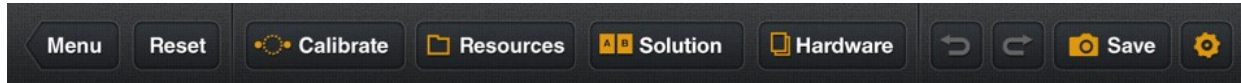
Menu: Press this button to return to the Main Menu. Caution: Save your work before returning to the Main Menu. If you return to the main menu without saving your work and then select a new case, you will lose all your work.

Reset: Press this to clear all your work (arrows, cut-outs, angles) and return to the clean, original x-ray. Caution: Save your work before pressing the reset button.

Calibrate: You should calibrate the magnification (mag) marker before working on a case. After you press the calibrate button, a circle tool will appear. Grab the blue calibration circle by the dotted circumferential line and drag it over the magnification marker. Resize the dashed circular line so that it is centered on the edge of the magnification marker by using the two solid blue balls on either side of the circle (see figure to the right). Then enter the diameter of the magnification marker in the calibrate field at the top of the screen. Our pre-loaded cases contain one-inch (2.54-cm) diameter magnification markers. Be sure to press the save button to record your calibration value. We recommend that all your x-rays contain magnification markers.
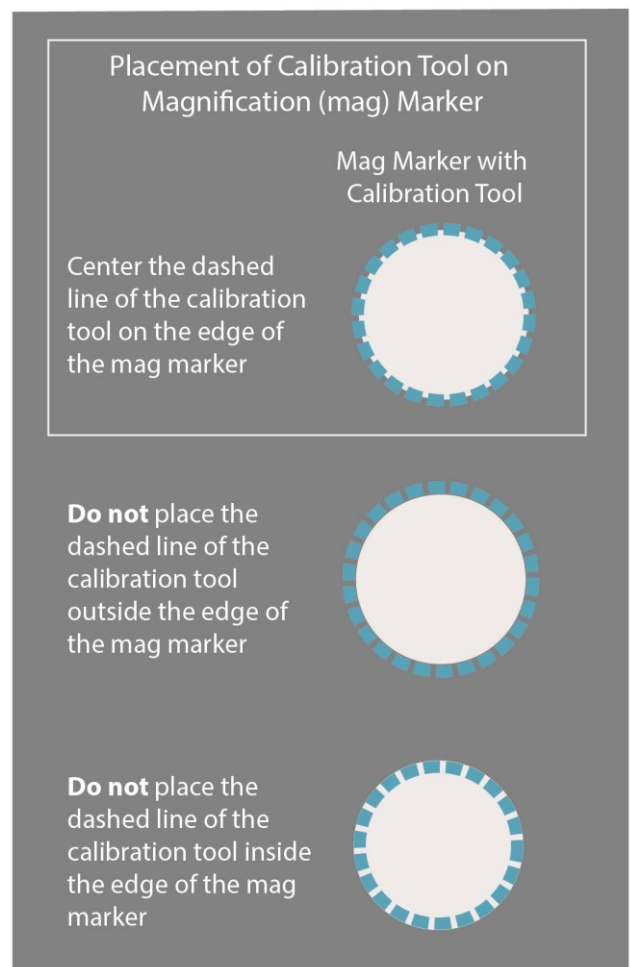
Resources: Press this button to see additional resources including the quick start guide and the standard measurements of the foot and lower limb (normal values for LDFA, MPTA, etc.).

Solution: Press this button to compare your work on a pre-loaded case to our solution of that case. This button will also allow you to compare a case that you loaded into Bone Ninja. In this situation, you will be able to compare the image with your work (lines, etc.) to the original version of that image.

*Hardware***:** Press this button to add hardware to your image. This tool is not for surgical planning purposes.

Un-do (back arrow icon): Press this button to take you back a step.

Re-do (forward arrow icon): Press this button to take you forward a step.

Save: Press this button to save your case by e-mailing it or by saving it as a JPEG in the Bone Ninja Photo Album. When you press the send via e-mail option, your e-mail program will launch and the image will be included as an attachment. After you save an image or send it via e-mail, you cannot modify the elements (lines, cut outs) within the Bone Ninja app. You can, however, use Bone Ninja to make new lines and new cut outs on a saved image.

Settings (gear icon): Press this button to show/hide auto angles, show/hide "nudge" arrows, and increase/decrease line thickness. When Auto Angles is on, it will automatically insert angle measurements after you draw intersecting lines. When the Nudge Tool is on, four small arrow buttons will appear in the bottom left of the deformity correction screen that allow you to move selected elements in small increments. You can choose for your lines to be thin, medium, or thick. We recommend that you turn on thick lines when you are giving a presentation using Bone Ninja and need the audience to be able to see your work.

Toolbar (on the left side of the Deformity Correction screen)

Deformity Correction Toolbar

Select/Move Tools:
Use to select and move objects. Press and hold the button to choose different options.

Draw Lines/Select Line Color:
Use to draw lines. Press and hold the button to select line color.

Cut Out Tool:
Selects the fragment that needs to be cut.

Thumbtack:
Allows you to choose a rotational point of correction.

Annotations:
Allows you to write text on the image. Press and hold the button to choose different options.

Ruler:
Measures the distance between two points.
Note: First calibrate image or your measurement will not be accurate.

Protractor:
Measures the angle between two lines. If Auto Angles (Settings menu) is "on", angles are measured automatically.

Angle Templates:
Allows you to insert an adjustable angle template.

Tick Mark Tool:
Allows you to draw a line that is divided in half or into thirds or fifths. Press and hold the button to select how the line will be divided.

Draw Point/Select Point Color:
Draw points (not lines). Press and hold the button to select different colors.

Show/Hide Toolbar

To select a tool, press that button (it will become highlighted). Some buttons have additional options that appear when you press and hold a button.

Select/Move Tools

The Select/Move Tools allow you to select an element and modify it (move it, angle it, shorten it). If you press and hold the button, additional selection tools will appear. Press the Select/Move Tool and then make your modifications. When an object is selected, it temporarily becomes a light blue color. To unselect an object, tap on the far edge of the screen and then it will revert to its native color. When you use this tool to select a line, a menu bar will appear that shows you the line length, allows you to "lock" that line so that it cannot be moved, and gives you an option to delete the line. If you lock a line and then wish to move it, use the Select/Move Tool to select the line and then press the unlock button. If you wish to group two objects, such as a line and a cut-out section, then you can keep touching different objects and they will all turn light blue and be linked. If the select tool is active and you wish to draw a line, you must go back and press the Line Tool.

Line Tool

You can press the Line Tool button to draw lines. If you press and hold the Line Tool button, a color palate appears and allows you to choose the color of the line.

Cut Out Tool

Use the Cut Out Tool to simulate osteotomies. After you select the tool, you can encircle an object with dots. When you close the circle of dots, that area inside the dots will be treated as an object that can be selected, moved, and rotated. It can also be grouped with lines.

Thumbtack Tool

The Thumbtack Tool allows you to choose a rotational point of correction. Use the Cut Out Tool to encircle an object with dots and create a fragment. Select the Thumbtack Tool. Tap on the fragment to make the Thumbtack appear. Then press and drag the Thumbtack icon to move it to a new location. When you press and drag on the rotational handles (arrows inside circles), the fragment will now rotate around the thumbtack.

Annotations Tool

The Annotations Tool allows you to make notes on the image. These notes can later be selected with the select tool (turning light blue) and then moved, rotated, locked, or deleted. If you press and hold the button, a color palate appears and allows you to choose the color of the text.

Ruler Tool

The Ruler Tool measures the length of a line. Center the corner of each end of the ruler on the edge of the object to be measured.

Protractor Tool

The Protractor Tool measures the angle between two lines.

Angle Template Tool

The Angle Template Tool allows you to insert an adjustable angle template.

Tick Mark Tool

Allows you to draw a line that is divided in half or into thirds or fifths. Press and hold the button to select how the line will be divided.

Point Tool

The Point Tool allows you to draw points. If you press and hold that button, you select the color of the point.

Show/Hide Toolbar

If you press the orange tab at the bottom of the toolbar, you can hide or reveal the toolbar.

How to Simulate an Osteotomy by Cutting and Rotating a Fragment

For a quick demonstration, watch our YouTube video about simulating an osteotomy:
http://youtu.be/LcvhAyC8Bbo

To make an osteotomy, first select the Cut Out Tool. Use the Cut Out Tool to select the object that you would like to manipulate. Place the dots to create a continuous dotted line around the area that you would like to manipulate (i.e., fragment). Then select the Thumbtack Tool. When you tap on the new fragment, a thumbtack will appear in the center of the fragment. You can press and drag this thumbtack to a new location (e.g., the apex of the deformity). When you press and drag on the rotational handles (arrows inside circles), the fragment will now rotate around the thumbtack.

You can also group objects so that multiple objects (e.g., fragment, lines) rotate around the thumbtack. Use the Cut Out Tool to create a fragment. Then select the Thumbtack Tool. Tap on the fragment that you have cut out. Then group your objects by tapping on your fragment, lines, or other objects, which will make them turn light blue. This means that they are now grouped together. Then drag the thumbtack icon to the point that you would like all the objects to rotate around. Use the rotational handles (arrows inside circles) to rotate the entire grouped selection. Tap on the far edge of the screen to unselect these objects.

How to Simulate Double and Triple Level Osteotomies

Bone Ninja also allows you to simulate double-, triple, and even four-level osteotomies. The best strategy is to start by drawing lines to represent the individual axes of the segments and then determine the apexes of the various deformities. When making osteotomies, we recommend that you start distally and work your way proximally. Use the Cut Out Tool to select the most distal segment, ending it at the level of the intended osteotomy. Select the Thumbtack Tool, tap on the fragment (the dotted lines will turn light blue), and then tap on the line associated with that segment (the line will turn light blue). Drag the thumbtack icon to the apex of the deformity, typically on the convex cortex. Use the rotational handles (arrows inside circles) to rotate the grouped objects (fragment plus the associated line) to align them with the segment above. Once you are satisfied with the position of the objects, tap on a far edge of the screen to unselect these objects.

If you want to perform another osteotomy that is proximal to the first one, start by using the Cut Out Tool to draw an outline around the new area of interest that is above the previously rotated fragment. Do not cut out the entire bone distal to the second osteotomy, but rather just the part above the previously cut out distal segment, up to the level of the next osteotomy. You will now have two separate selected bone segments that should not overlap (or overlap by only a small amount). Next select the Thumbtack Tool, tap on the fragment, and then select all the objects that you would like to move, including the original distal cut out, the new proximal cut out, and the two lines that are associated with these bone segments. You will now have four separate objects selected, and all will turn light blue. Move the thumbtack icon to the level of the second osteotomy, and then use the rotational handles to move the entire grouping of light blue objects as a unit. Once you are satisfied with the position, tap on the edge of the screen to unselect the objects. This process may be repeated to create a third or fourth osteotomy.

Rotating the Entire Leg Back into Alignment

After simulating osteotomies, the entire leg may be angled either medially or laterally. If you would like to rotate the *entire* leg back under the pelvis, perform the following steps:
1. Use the Cut Out Tool to select the remainder of the femur/tibia above the area(s) that you have previously selected and realigned. In this final scissored area, include the femoral head.
2. Choose the Thumbtack Tool and select ALL the objects on the screen, including all the fragments and planning lines. They should all turn light blue.
3. Move the thumbtack icon up to the femoral head, and then use the rotational handles to rotate the entire leg back under the hip until the leg appears upright.

Chart for Deformity Planning Values

<table>
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Measure MAD
Frontal/Sagittal Planes
MAD (cm)
R ☐ L ☐

Analyze Joint Angles
Frontal Plane

mLPFA ☐   aMPFA ☐
90° (85–95°)   84° (80-89°)
R ☐   L ☐

mLDFA ☐   aLDFA ☐
87° (85–90°)   81° (79-83°)
R ☐   L ☐

MPTA 87° (85–90°)
R ☐   L ☐

LDTA   89° (86–92°)
R ☐   L ☐

Sagittal Plane
PDFA 83° (79–87°)
R ☐   L ☐

PPTA 81° (77–84°)
R ☐   L ☐

ADTA 80° (78–82°)
R ☐   L ☐

SMAA 0°
R ☐   L ☐

SJLA 16°
R ☐   L ☐

Pick Bone To Treat
Femur R ☐   L ☐

Tibia R ☐   L ☐

LLD
Lift (cm) R ☐   L ☐

Segments (cm)
Pelvis R ☐   L ☐

Femur R ☐   L ☐

Tibia R ☐   L ☐

Foot R ☐   L ☐

Overall LLD
R > L ☐   R < L ☐

☐ cm

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</td></tr>
</table>

The right hand side of the Deformity Correction screen has a chart with values that you can fill in as you proceed with your analysis. To view this chart, press on the orange button in the bottom right of the Deformity Correction screen. You may fill out all or part of the chart, according to your needs. To hide the chart, press the orange tab located on the bottom right of the chart. The values that you enter will remain even if you hide the chart.

The order of the items in the chart reflects the mnemonic "MAP" that we recommend:

M – **M**easure the MAD
A – **A**nalyze the joint angles
P – **P**ick the bone to treat

After you have completed the MAP analysis, you can then perform the "ABCs":

A – determine **A**pex of deformity
B – choose a **B**one cut level
C – choose a **C**orrection level and type

Acronyms Used in the Chart	
ADTA	anterior distal tibial angle
aLDFA	anatomic lateral distal femoral angle
aMPFA	anatomic medial proximal femoral angle
L	Left
LDTA	lateral distal tibial angle
LLD	limb length discrepancy
MAD	mechanical axis deviation
MAP	**M**easure MAD; **A**nalyze joint angles; **P**ick the bone
mLDFA	mechanical lateral distal femoral angle
mLPFA	mechanical lateral proximal femoral angle
MPTA	medial proximal tibial angle
PDFA	posterior distal femoral angle
PPTA	posterior proximal tibial angle
R	Right
SJLA	sagittal joint line angle
SMAA	sagittal mechanical axes angle

Contact Us

If you have any questions or experience any problems, please e-mail us at icll@lifebridgehealth.org or leave a comment on our Facebook page at www.facebook.com/LimbLengthApps.

References

1. Blane CE, Herzenberg JE, DiPietro MA. Radiographic imaging for Ilizarov limb lengthening in children. Pediatr Radiol. 1991;21(2):117–20.
2. Hambardzumyan V, Herzenberg JE. Bone Ninja app as a body image simulation tool for shared decision-making. J Limb Lengthening Recon. 2019;5(2):105–110.
3. Paley D (Herzenberg JE, ed). Principles of deformity correction. Berlin: Springer-Verlag; 2002.
4. Paley D, Herzenberg JE, Tetsworth K, McKie J, Bhave A. Deformity planning for frontal and sagittal plane corrective osteotomies. Orthop Clin North Am. 1994;25(3):425–65.
5. Whitaker AT, Gesheff MG, Jauregui JJ, Herzenberg JE. Comparison of PACS and Bone Ninja mobile application for assessment of lower extremity limb length discrepancy and alignment. J Child Orthop. 2016;10(5):439–43.