Biomet Multi-Axial Correction (MAC) System

Surgical Technique
Introduction

The Biomet MAC (Multi-Axial Correction) System is an external fixation system with the unique ability to gradually or acutely correct single or multi-planar deformities of the extremities utilizing two planes of angulation and two planes of translation, rotation and lengthening. The MAC System is a component system that allows the correcting mechanism to be applied directly at the point of deformity to minimize secondary deformities.

Through compatible rails, rings, and arcs, bone screws can be applied to the limited safe zones of human anatomy. This reduces soft tissue injuries and stiffness. In turn, the need for physical therapy declines. With the MAC System, it is possible to accomplish all this without compromising accurate and efficient correction of deformity.

Injury, birth defects, tumors, growth disturbances, and metabolic diseases can cause deformities of the limbs. Since the mid 1980’s, complex multi-planar deformities have been treated using ring fixation systems. Ring fixation revolutionized the ability of the orthopedic surgeon to correct such complex deformities. However, these same ring fixators can be bulky, cumbersome and complicated to use, for both the treating physician and the patient. Failure to correctly apply any fixator can lead to residual or secondary deformities. Such deformities can then be difficult or impossible to correct with standard fixators.

The MAC System allows for accurate correction of the limb deformities. It also provides the ability to directly correct those common secondary deformities, inherent in, and resulting from corrections with external fixators, by simply dialing in the multi-planar corrections.
Indications and Contraindications

INDICATIONS
The Biomet Multi-Axial Correction (MAC) System is an external fixation device intended for use in the treatment of bone conditions including leg lengthening, osteotomies, arthrodesis, fracture fixation, and other bone conditions amenable to treatment by use of the external fixation modality.

CONTRAINDICATIONS
Patients with mental or neurologic conditions who are unwilling or incapable of following postoperative care instructions.
Adult Multi-Axial Correction (MAC) Deformity System
Catalog No. 00048

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Tray Layouts

XS MAC Tray

XS MAC Module

XS Fixator Complete
1 Knuckle XS Fixator
2 Knuckle XS Fixator
3 Knuckle XS Fixator

XS Ring - Female Adapter
XS MAC - Female Adapter
XS Ring - Male Adapter

XS Rotating Ring
XS Slotted AC
XS Fixator T-Clamp
XS Ring Bolt
XS Variable Screw Carriage
XS Bone Clamp

XS Rails, Clamps and Bridges
### XS Multi-Axial Correction (MAC) Deformity System

Catalog No. 00049

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Device Description

The pictures below represent two examples of secondary procurvatum deformities resulting from (Picture A) lengthening with a standard rail (note poor anterior bone formation) and (Picture B) a circular ring correction of Blounts tibia vara. With the MAC System, these deformities can be corrected simply, without returning to the O.R., or performing lengthy adjustments of the construct. *

The MAC System is less bulky than ring systems, easier to adjust and easier for the patient. Unlike some of the newer complex ring systems, the MAC System can be applied to any location on the limbs. Furthermore, it eliminates the need for a computer to guide the correction.

The Biomet MAC System is a versatile, multi-directional single level deformity correcting component external fixation system, which is designed to be applied at the CORA, or Center of Rotation and Angulation, (CORACentric, see page 10) to reduce secondary (iatrogenic) deformities. It can allow angular correction in two planes at 90° to each other. It can allow translation in two planes at 90° to each other. It can allow distraction and compression using a variety of rails and rods. The MAC System can correct rotation about the mechanical axis of the limb through a system of rotating rings. The MAC System is a component system and compatible with other Biomet systems such as the Adult Rail, DynaFix Vision System, Construx, and XS Rail.

To learn more about finding CORA, see the Technique Overview Section.

*Results from case studies may not be predictive of results in other cases.
The MAC System can also be applied in a plane perpendicular to the CORA (CORA-Perpendicular). When placed along the bisector of the CORA, full deformity correction will occur with varying amounts of lengthening or shortening, whichever may be desirable. See page 14.

The MAC System can also be placed off the CORA, but nearby (CORA-Proximal), using the multi-directional components of the device to correct secondary translation. See page 17.

Translation errors due to miscalculation and errors of centering can be corrected after application using the MAC System’s ability to angulate in two planes, translate in two planes, lengthen and shorten, as well as rotate the deformity.

Once the CORA is identified, a guide pin is inserted into the CORA and the MAC System is centered over it and the screws and wires are safely added on. It is user friendly and allows for correction of errors (residual deformity) without returning to the operating room. It allows multi-planar application of wires or half pins for increased strength.

Deformity Assessment

1. Malalignment, mechanical and anatomic axis assessment
2. Joint orientation assessment
3. CORA Assessment
4. Oblique plane assessment; angulation and translation
5. Principles of lengthening, including rates of healing, soft tissue stretching, etc.
6. Principles of angulation: Paley Rules 1, 2, 3, hinge placement, the Bisector Rule, iatrogenic translation, etc.
7. Calculation of rates of safe angulation, The Angulation Rate Guide
8. Concept of iatrogenic deformity, i.e. translation from Angulation Correction Axis (ACA) not being on CORA
**Technique Overview**

**Manual Of System Techniques**

The Biomet MAC System can be applied in three different locations with respect to the CORA: CORA-Centric, CORA-Perpendicular and CORA-Proximal. Each permits correction in a unique way.

The CORA-Centric method places the fixator hinge directly over the CORA, minimizing unintended translation.

The CORA-Perpendicular application places the fixator hinge on the bisector of the deformity. Placement on the convex side of the deformity will produce lengthening while placement on the concave side of the deformity will produce shortening. This application should be employed when such lengthening or shortening is desired.
The CORA-Proximal application places the fixator hinge near the CORA. The placement of the hinge on the concave or convex sides of the deformity will cause shortening or lengthening, respectively. The placement of the hinge proximal or distal to the bisector line will cause lateral translation. This application should be used when the hinge cannot be placed directly over or perpendicular (on the bisection) to the CORA. The surgeon must calculate that the unintended translation can be corrected by the angulation and translation screws.
Surgical Technique

CORA-Centric MAC System Application

**NOTE:** In this example the Adult MAC System will be used to demonstrate the application.

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**Step 1:** Identification of the CORA, see the Technique Overview

**NOTE:** Allow for at least 1 cm of shortening or lengthening to allow for compression, distraction and clearance of bone edges during angulation.
Step 2: Place a temporary K-wire (3.2 mm Adult / 1.6 mm XS) as a guide wire axially through the CORA. If this would harm neurovascular or other tissues, mark the skin and hold the device in place manually on a two-finger breadth spacer.

Step 3: Place a two-finger breadth spacer on the skin over the guide wire.

Step 4: Place the centering hole of the MAC System (marked “Primary”) through the guide pin to rest on the spacer.

NOTE: The primary hinge is capable of 80° and the secondary hinge is capable of 30°-50°. If the guide pin is placed perfectly, the deformity can be fully corrected with the primary hinge. However, it is difficult to place the pin perfectly in the CORA, and this will result in a small iatrogenic angulation, translation, and rotation. The versatility of the system allows for easy correction of these secondary deformities.

Step 5: Adjust the hinges so that the arms of the MAC System are parallel to the CORA divisions of the deformed bone. The translation screws should be centered unless a larger translational deformity is to be corrected, in which case, the translation screws should be positioned to accomplish that correction.

Step 6: Beginning with the end of the MAC System closest to a joint, assess the anatomy to determine the safest and strongest location for bone screw and/or pin placement. Shorter distances to the bone are likely to be strongest. Then, select from the components (simple bone clamp, arcs, rings, rails, etc.) the component that will connect the MAC to bone screws. Fix the desired component to the end of the MAC System. Choose a connection device that will allow the best fixation and desired lengthening.

Step 7: For the end of the MAC System opposite the closest joint, assess the anatomy to determine the safest and strongest location for bone screw and/or pin placement. Shorter distances are likely to be strongest. Then select from the components (simple bone clamp, arcs, rings, rails, etc.) and fix to the opposing end of the MAC System.

Step 8: With the MAC System in position, begin fixation (bone screws and/or wires) closest to the nearest joint. Then place fixation farthest from this point, making adjustments to assure that all fixation devices (bone screws and/or wires) will fixate the bone through diameters of bone. Add additional fixation as warranted to accomplish correction. Generally three fixation points (bone screws) on either side of the osteotomy are recommended.

Step 9: Remove guide pin. The Osteotomy is performed at the CORA unless there are concerns about the bone quality or other anatomic problems, such as ligaments, physes, etc.

Step 10: It is generally best to wait 5-10 days, depending on age and other factors, before lengthening or correcting angular deformity.

NOTE: The translation screws move at a rate of 1 mm per 360° turn of the appropriate screw. The angulation hinges correct at 4° per 360° turn of the appropriate screw. Angulation causing lengthening or translation should proceed at a rate of 1mm/day for nerves at risk or bone. Faster rates may lead to permanent nerve damage or delayed and nonunion. The amount of lengthening for structures at a specific distance from the hinge are calculated using the “Angulation Rate Guide”, (See page 20-24).
Surgical Technique (Continued)

CORA-Centric Application, Oblique Plane Tibia Deformity
CORA-Centric Application, Blounts Proximal Tibia Vara, Rotation Rings

Correcting Rotation
CORA-Perpendicular MAC System Application

A CORA-Perpendicular construct is primarily recommended when the MAC System can be safely applied to the convex side of a deformity where length is desirable. It can also be used where a lower profile device is desired; however, calculation of the length change must be made and the device set up to correct for such length changes.

A simple method to approximate the length change in CORA-Perpendicular applications:

1. On the X-Ray, at the level of the osteotomy, mark the position of the fixation device at 2-3 cm from the skin.
2. Draw a line perpendicular from the bone to this point (distal to the deformity).
3. Take a ruler and place along this line. Pivoting on the point, rotate the ruler until it is perpendicular to the upper bone (other side of the deformity). Measure the length change along the bone.

Step 1: Identification of the CORA. (see Technique Overview). Identify the bisector line, (see Technique Overview). Determine the amount of lengthening or shortening needed. NOTE: the device should be planned for at least 1 cm of shortening or lengthening to allow for compression and clearance of bone edges during angulation.

Step 2: The primary hinge should be aligned along the bisector, perpendicular to the CORA. Align the primary hinge at the level of the bisector with the arms of the MAC System parallel to the upper and lower limbs of the bone deformity.

NOTE: as the MAC System is being applied perpendicular to the CORA, the axis is not on the CORA and the guide wire cannot be used.

Step 3: Select from the components (simple bone clamp, arcs, rings, rails, etc.) and fix to the end of the MAC System. Choose a connection device that will allow best fixation and will allow adequate lengthening. Assemble the device.

Step 4: Place a two-finger breadth spacer on the skin at the guide wire site.

Step 5: Adjust the hinges so that the arms of the MAC System are parallel to the limbs of the deformed bone. There should be at least a two-finger breadth space between the skin and the device along it's entire length.

Step 6: Beginning with the end of the MAC System closest to a joint, assess the anatomy to determine the safest and strongest location for bone screw and/or pin placement. Shorter distances are likely to be strongest.

Step 7: For the end of the MAC System farthest from the closest joint assess the anatomy to determine the safest and strongest location for bone screw and/or pin placement. Shorter distances are likely to be strongest. Then select from the components (simple bone clamp, arcs, rings, rails, etc.) and fix to the end of the MAC System.
Step 8: With the MAC System in position, begin fixation (bone screws and/or wires) closest to the nearest joint. Then place fixation farthest from this point making adjustments to assure that all fixation devices (bone screws and/or wires) will fixate the bone through diameters of bone. Use the lengtheners, angulation and translation screws to position the primary hinge along the bisector. Add additional fixation as warranted to accomplish correction. Generally three points of fixation above and below the osteotomy are suggested.

CORA-Perpendicular, Femur Application
Surgical Technique (Continued)

Check to be sure that there is enough lengthening and shortening available to obtain the desired length, as well as compression if needed.

Step 9: The translation portions should be centered unless translation deformity is to be corrected, in which case, the translation screws should be positioned to accomplish that correction.

Step 10: Osteotomy is performed.

Step 11: It is generally best to wait 5-10 days, depending on age and other factors, before lengthening or correcting angular deformity.

NOTE: The translation screws move at a rate of 1 mm per 360° turn of the appropriate screw. The angulation hinges correct at 4° per 360° turn of the appropriate screw. Angulation causing lengthening or translation should proceed at a rate of 1 mm/day for nerves at risk or bone. Faster rates may lead to permanent nerve damage or delayed and nonunion. The amount of lengthening for structures at a specific distance from the hinge are calculated using the "Angulation Rate Guide" (See page 20).

*NOTE: In this example of CORA-Perpendicular application, a second osteotomy was performed to acutely correct a lesser second deformity at a different level than the larger deformity. (See steps 1-11 for detailed explanation of correction).

*Results from case studies may not be predictive of results in other cases.
*Example Of XS MAC System Used On The Forearm In A CORA-Perpendicular Application

*Results from case studies may not be predictive of results in other cases.
Surgical Technique (Continued)

CORA-Proximal MAC System Application

This application is used when the fixator cannot be placed at the CORA (CORA-Centric) or along the bisector (CORA-Perpendicular). The translation, angulation and rotation screws are needed to correct the secondary deformities caused by failure to place the device at the CORA.

Below is an example of CORA-Proximal application using the XS MAC System for proximal tibia vara, Blounts, with a CORA very close to the joint. Note how the translation device is used to correct the secondary translation due to not placing the MAC System directly over the CORA.
Rotation Ring Application

- With proper pre-operative planning, up to 90° of rotation can be accomplished with any of the various diameter rotation rings.

- In order to avoid unintended translation when using the MAC System Rotation Arc, it is necessary to center the arc on the mechanical axis of the limb and keep the plane of the arc perpendicular to the mechanical axis.

- Here is a simple method of centering the arc on the mechanical axis using two equal length bone screws at different angles. The arcs are available in four sizes representing the diameter of the inner edge of the arc. The bone must be centered within the arc. If two bone screws hold the bone at a radius length from the inner edge of the arc, then the bone will be centered. Each bone screw must be the length of the radius of the arc, plus half the diameter of the bone to which it is attached (at the level of attachment), plus the thickness of the rotation arc, plus the width of the bone screw clamp, plus 1 cm beyond the bone screw clamp (to allow for the wrench).

The Formula

Diameter of bone + radius of ring (inner edge of rings) + thickness of the ring + width of the bone screw clamp + 1 cm for placing the wrench.

- If two screws at two different locations along the arc are screwed along a diameter of the bone into two cortices and have 1 cm of length beyond the bone screw clamp, then the bone will be centered within the arc.

- Any unintended or undesired translation can be corrected using the angulation and translation screws of the MAC System.
Using The Angulation Rate Turn Guide

Left/right, varus/valgus, wrench placement one side or the other, turn clockwise/counterclockwise, etc has always been a variable in every device designed to gradually correct deformity. The surgeon must always decide which screw to turn and in which direction to turn it. Before the Angulation Rate/Turn/Guide (ARTG), the surgeon pointed to the screw, told the patient to place the Allen wrench and “turn in this direction.”

This has not changed. What has changed is that the patient will receive a card (ARTG) with instructions that tell him/her to place the wrench into the screw, turn it in a specific direction and a specific amount. The doctor will show the patient where to place the card, in just the same way.

For example: with the MAC System, the doctor might tell the patient to place the Allen wrench into the primary screw from the lateral side, place the ARTG facing laterally and line the filled-in wedge edge with the handle of the wrench. The doctor will have marked the ARTG with an arrow so the patient will turn in the direction of the arrow to the other side of the filled-in wedge.

The reverse side of the ARTG will have the directions, the frequency of turning (usually 4x/day), and the number of days to turn.

How to determine the direction of turning is a little harder. Which arc to turn is easy. The doctor should know where the deformity is and which arc is in the plane of that deformity. Choosing the side of the screw to turn should depend on convenience to the patient or parent who is turning it, that is, where is it easiest to reach for the person turning. There is enough play in the device to turn the screw 90° either way, watching the hinge’s teeth move, without hurting the patient. This allows the doctor to make a trial “double check” in the office on the day instructions are given to the patient (usually on the 7-10th day) so he is sure which way he wants the patient to turn the screw. [The doctor should have done this trial in the O.R. when he first put the MAC System on.] Instructions are then given to the patient and written on the ARTG.

The other method to determine which way to turn the screw is to know that the screw works with the “right hand rule.” The screw will move along the teeth of the arc. If one points his right thumb along the axis of the screw, in the direction he wants the screw to travel, he should turn the screw in the direction of the fingers of his right hand. Doing this will move the screw along the teeth of the arc (usually the teeth are showing out of the MAC). That is the correct direction.

Draw right hand with thumb pointing to part of arc that is visible (shiny) i.e., to the left. Fingers of the hand tell which way to turn. The only thing that the ARTG has added is a way for the doctor to figure out for himself and then tell the patient how much to turn. There is also the advantage of giving the patient a piece of paper with directions for what to do and a phone number to call in case of problems. Generally, soft tissues and bone can be safely lengthened at a rate of 1 mm per day. Faster lengthening of bone can lead to poor bone formation or delayed and nonunion. Slower distraction may lead to premature consolidation.
Angulation along the bisector line of a deformity leads to lengthening or shortening. The amount will be determined by both the rate of angulation and the distance from the hinge.

The actual amount of lengthening or shortening can be calculated trigonometrically using the rule of simple triangles or arcs.
Using The Angulation Rate Turn Guide (Continued)

It is important to evaluate the anatomy and decide which structures should be lengthened at the rate of 1 mm per day. Tissues closer to the hinge will lengthen slower while those farther from the hinge will lengthen at a faster rate.

\[
\text{Distraction Rate} = \text{Distractor circle radius} \times 1\text{mm/day}
\]

Regenerate circle radius
Using the rule of simple triangles, a table can be made to show the degrees of angulation needed to obtain 1 mm of length at distances of 1 cm to 15 cm from the angulating hinge. A card (The Angulation Rate/Turn Guide, ARTG) has been developed to facilitate determining how fast to change the angle for correction of deformity and to provide simple instructions to the patient.

<table>
<thead>
<tr>
<th>Distance of fixator pivot to nerve in centimeters</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rate of adjustment four times per day to effect 1 mm of distraction at desired structure</td>
<td>$\frac{3}{8}$</td>
<td>$\frac{3}{16}$</td>
<td>$\frac{1}{8}$</td>
<td>$\frac{3}{32}$</td>
<td>$\frac{1}{16}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$\frac{1}{32}$</td>
</tr>
</tbody>
</table>

# of turns of wrench (360° turn of wrench = 4° on device)
Using The Angulation Rate Turn Guide (Continued)

With this card, the distance between the hinge and the structure to be lengthened 1 mm per day is measured with the ruler at the top.

The table is then used to determine the rate of angulation and distraction. For example, if the distance between the hinge and the structure to be lengthened is 7mm, and the goal is to keep the structures lengthening at 1 mm per day then the chart specifies an angulation rate of 1/16 of a circle (of 360°) four times per day.

The doctor will determine the direction to turn and mark this on the ARTG and fill in the wedge to be turned.

The physician will then show the patient which screw is to be turned. The Allen wrench is then placed into the screw. The ARTG has a notch, which is place on the Allen wrench and the patient is instructed in how to turn the screw.

Above: Example of ARTG: Distance between hinge and bone is 8 cm. ARTG advises a rate of 1/16 turn q.i.d. to obtain 1 mm of length per day. In this example, two weeks of 1/16 turn q.i.d. resulted in 14 mm of length.
Applications

- Reduction of acute fractures: Thin wires and olive wires can be used to reduce a fracture about the knee and ankle with rings. These rings are then attached to the MAC System for realignment to the diaphysis.

- Single level deformity whether it is in the frontal, sagittal or oblique plane.

- Proximal tibial deformities such as Blount’s Disease where the CORA is centered on the anatomic axis.

- Proximal tibial (High tibial osteotomy) osteotomy to alter tibial plateau weight bearing such as in DJD of the knee. By placing the mechanical hinge directly over the CORA, which is at the lateral cortex in these cases.

- Fracture treatment, especially where late deformity could be a problem such as in tibial plafond fractures which migrate into varus or where late compression may be needed to attain healing.

- Radial club hand.

- Mal/delayed and nonunions of the extremities.

Lengthening resulting in pin bending. MAC System as able to correct the resultant deformity.
*Case Examples - Ollier’s Disease*

**PRE OP:** Young girl with short and deformed upper arm from Ollier’s Disease.

**POST OP:** Gradual lengthening (9 cm) and correction was achieved with an **Biomet MAC** frame.

*Results from case studies may not be predictive of results in other cases.*
**FOLLOW UP:** She now has equal arm lengths...

...and full mobility.

*Results from case studies may not be predictive of results in other cases.*
Case Examples - Charcot Foot Collapse

**PRE OP:** X-Ray and picture demonstrating foot collapse and valgus deformity

*Results from case studies may not be predictive of results in other cases.*
POST OP: Restored arch height and correction of valgus deformity are now visible

*Results from case studies may not be predictive of results in other cases.
Case Examples - Multi-planar Femoral Deformity

Figure #1: Left Proximal Femoral Focal Deficiency (PFFD) with short femur, mid-diaphyseal varus deformity, and distal femoral valgus deformity

Figure #2: PFFD, lateral x-ray, procurvatum deformity

Figure #3: PFFD, AP x-ray, XS MAC CORA perpendicular application for simultaneous correction of length and angulation

Figure #4: Clinical view, front

Figure #5: Clinical view, lateral

Figure #6: AP x-ray with XS MAC after correction

Figure #7: AP view, XS MAC after correction

*Results from case studies may not be predictive of results in other cases.*
14 year old male with short tibia secondary to fibular hemimelia. The fibula can be stabilized using two arcs on the MAC to reach laterally, allowing screw insertion into the proximal and distal fibula.

*Results from case studies may not be predictive of results in other cases.
Application Examples (Continued)

XS MAC - Supramalleolar Osteotomy Clubfoot Correction
Radial Club Hand Application
Femur Application utilizing the Ring C/D Mechanism
Blounts Correction utilizing the Adult MAC

XS MAC - Supramalleolar Osteotomy Clubfoot Correction
Radial Club Hand Application
Femur Application utilizing the Ring C/D Mechanism
Blounts Correction utilizing the Adult MAC

Club Foot Correction
Lateral Placement of XS MAC

Blounts Correction utilizing the XS MAC
XS MAC for Derotational Osteotomy

Foot Arch Correction
Superior Placement of XS MAC

*Results from case studies may not be predictive of results in other cases.*
Additional Biomet Options To Consider

**Trauma**
- Biomet Carbon Adult & Small Rail System
- Biomet Pediatric Locking Nail (PLN) System
- Biomet Hip Distractor

**Spine**
- Array
- Polaris A New Synergy Spine System

**Osteobiologics**
- InterGro DBM Putty, Paste and Plus
- Biomet BMA Kit
- Biomet BHS-Mini

**Bracing**
- Cervical Collar
- Wrist Brace
- Canvas Rocker Bottom Case Shoes

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Further Information

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