The Cartilaginator™: A Comprehensive Overview of Its Uses and Versatility

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Background

Arthrodesis procedures are indicated for arthritic, painful, and degenerative conditions of the ankle, hindfoot, midfoot and forefoot that are unresponsive to non-operative management.[i] Meticulous joint preparation with removal of the cartilage is crucial for bony apposition and union of the targeted joint.[ii, iii, iv] Multiple techniques have been described for preparing the joint, including no preparation, the use of manual preparation techniques such as curettes and osteotomes, fenestrations, as well as several different instruments using both traditional open and minimally invasive (MIS) techniques. Zhao et al found that MIS joint preparation was equivalent to traditional techniques with much smaller incisions in cadaveric samples. While the use of burrs and minimally invasive approaches have shown promising results in several short term and cadaveric studies, there is little consensus regarding the superiority of any specific joint preparation technique.[v] Similarly, some studies have shown a lower non-union rate with convex-concave preparation techniques, where the two joint surfaces are "matched" to one another.[vi]

Common pitfalls when performing joint preparation include failure to prepare the entirety of the joint as well as excessive time taken to perform the joint preparation. The former can limit the ability of the joint to fuse, while the latter can make the surgery more difficult to perform, more costly, and put the patient at a greater risk for complications.[vii] Contrastingly, automated preparation techniques may generate excessive heat, leading to thermal necrosis and reducing fusion rates.[viii]

The Cartilaginator™ (Extremity Medical LLC) is a joint preparation and bone contouring device that allows for thorough, meticulous joint preparation while potentially saving operative time when compared to traditional techniques. It can be employed using either an open or MIS approach and it allows the joint congruency to be maintained with its numerous different shape attachments, including concave and convex styles, which create matched, contoured surfaces. The device is designed to allow for time savings in the OR with the potential for improved thoroughness of joint preparation.

Below, we demonstrate the general technique for usage of The Cartilaginator™ and numerous case examples of its versatility throughout the foot and ankle.

General Technique

Approach and Joint Distraction

Accessing the joint can be done through the surgeon's preferred approach. It is author's experience that The Cartilaginator™ works well using minimally invasive joint preparation techniques with smaller incisions roughly the size of the chosen tip (1-2cm), however traditional open techniques may also be performed. Once joint distraction has been completed, we will typically begin with an osteotome and/or curette to roughen the joint surface and remove any accessible/loose cartilage. Alternatively, a surgeon may prefer to enter the joint directly with The Cartilaginator™. We have found initially roughening the surface with another instrument can lead to faster removal of cartilage with The Cartilaginator™, however further study is needed.

Introduction of The Cartilaginator™:

The Cartilaginator™ can be attached to multiple power systems. In our practice, we use a Stryker system 9 drill set at 40% of the maximum RPMs. The Cartilaginator™ can then be introduced through the incision. We recommend starting the product near but not in contact with the cartilage and then initiating joint preparation using a horizontal, "fanning" motion. We find that by starting away from the cartilage one can then control the pressure with which the tool is used against the bony/cartilage surface and aid in cartilage removal while controlling bone loss.

Fenestration/trephination of joint surfaces:

The product allows for self-fenestrating through its jagged edges, which theoretically provides excellent surfaces for apposition and healing. However, additional drill holes, "fish tailing", or other means of fenestration may be added at the surgeon's discretion.

Irrigation/removal of debris following joint preparation:

As with traditional joint preparation techniques, we recommend irrigation following initial usage of The Cartilaginator™ in order to remove debris and cartilaginous tissue which could interfere with osseous bridging. Similarly, the use of pulsatile or continuous irrigation to protect against thermal necrosis is at the discretion of the surgeon. We employ irrigation in every case from a bulb syringe, even in MIS joint preparation.[viii]

Cleaning the instrumentation:

The instrumentation can be cleaned using normal saline in a sterile cup. The instrument can be placed in the cup and run on power, which removes the cartilage build up within the teeth. It can then be reused throughout the surgery. Alternatively, a sterile wire brush is provided to clean the cartilage debris from the device.

Augmentation/Bone Grafting:

Biological augmentation or autologous bone grafting can be used at the author's discretion. While there is often a slurry created from running The Cartilaginator™, this material is typically removed during irrigation while using the device.

Disposal:

The devices are peel-packed, single use, with multiple tips, which are designed to conform to the different joints of the foot and ankle. This allows for matching joint preparation, which can aid in bony surface apposition and bone-to-bone healing.

Uses and Versatility

We find this tool is an efficient and effective tool which can be employed throughout the foot and ankle for bony surface contouring and joint preparation. Below are a few case examples of The Cartilaginator™'s usage in joint preparation.

Subtalar joint:

The subtalar joint can be approached either medially or laterally using traditional incisions. The author's preference is for an MIS Sinus Tarsi incision (Figure 1), however we also use an open approach on a case-dependent basis. A small osteotome or curette is introduced to begin the removal of cartilage. The convex and then concave tips are introduced, and the joint is prepared using a fanning motion, with bulb irrigation

used throughout the joint preparation. We then irrigate to remove particulate debris, which often contains cartilage (not conducive to fusion). In situations of severe deformity, the saw tip style can be used to help remove small portions of arthritic bone and help better achieve plantigrade hindfoot positioning.

Figure 1: MIS Sinus Tarsi Approach to the Subtalar Joint using The Cartilaginator™: the large, convex Cartilaginator tip is used to contour to the subtalar joint while the joint prep is performed. In this case, the instrument was inserted through an MIS technique with no distractor applied.

Talonavicular joint:

The Talonavicular joint traditionally has the highest overall nonunion rate following triple arthrodesis.[x] The joint can be approached through a either a dorsal or a direct medial incision. The author prefers the dorsal incision, between the tibialis anterior and tibialis posterior. The joint is accessed, and distraction can be achieved with a Hintermann and/or lamina spreader. The contour of the large convex device fits well to the distal surface (i.e. the proximal navicular) as shown, while the concave device can be used on the talar head preparation. We find the talonavicular joint is an ideal candidate for The Cartilaginator™, for the two tips allow for matched joint surfaces. Again, the saw tooth or cutting blade can also be used to reach the more lateral and inferior surfaces from a medial approach.

Compression and fixation can then be obtained with the author's preferred method. We have found that given the contouring of the joint after convex/concave matched joint preparation, minimal dead space and minimal osseous non-contact sites are created using this technique.

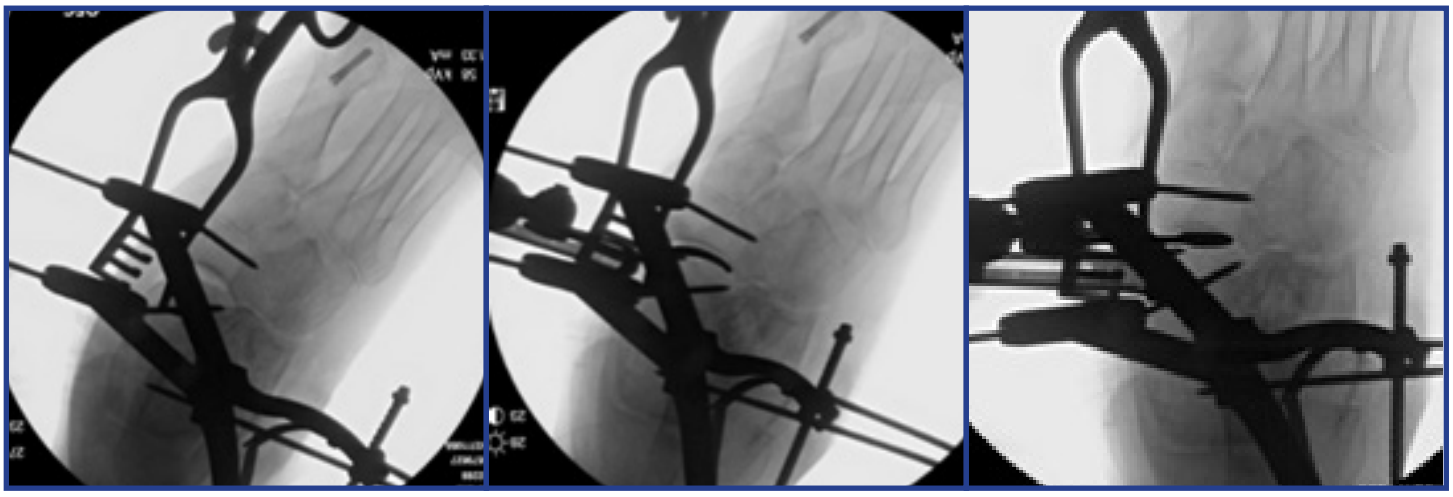

Figure 2: the Talonavicular joint is distracted using a Hintermann Distractor and The Cartilaginator™ is introduced. Note the conformity of the convex head in figure B to the distal surface, which allows for minimal bone loss during cartilaginous resection. The surgeon then used the saw tip style to access the most medial portion of the joint and further contour the joint surface before reducing the joint.

Tibiotalar joint:

Preparation of the ankle joint is typically performed using a lateral or anterior approach to the ankle. If a lateral approach is chosen, a fibulectomy may be considered using an oscillating saw or osteotome. However, it is the author's preference to preserve the fibula for potential future fusion takedown and conversion to total ankle arthroplasty. Manual distraction of the joint is performed with the surgeon's choice of distraction tool. Given the breadth of sizes available, The Cartilaginator™ can be introduced into the ankle joint with surfaces matching both the tibia and talus (figure 3). An MIS approach can be used to facilitate minimal morbidity and decreased OR time. The large convex and large concave devices are the author's preferred tips for the tibiotalar joint. In cases where there is a varus or valgus deformity, the device can be pressed into the bone to remove excess bone from the talus or tibia and achieve neutral coronal alignment.

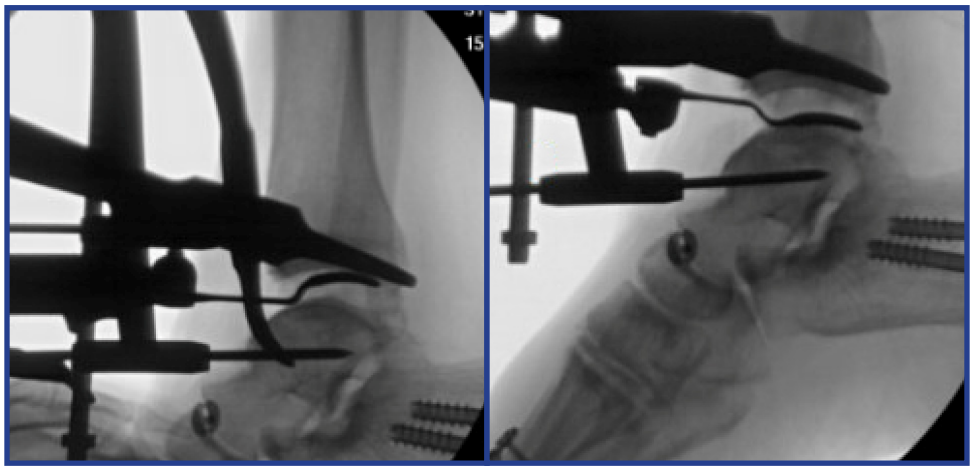

Figure 3: Tibiotalar Joint Preparation using The Cartilaginator™: Employing a lateral based approach and Fibulectomy, The Cartilaginator™ is used to prepare the ankle joint. Note that excess bone was removed from the medial Talus to attempt to offset the patient's varus deformity.

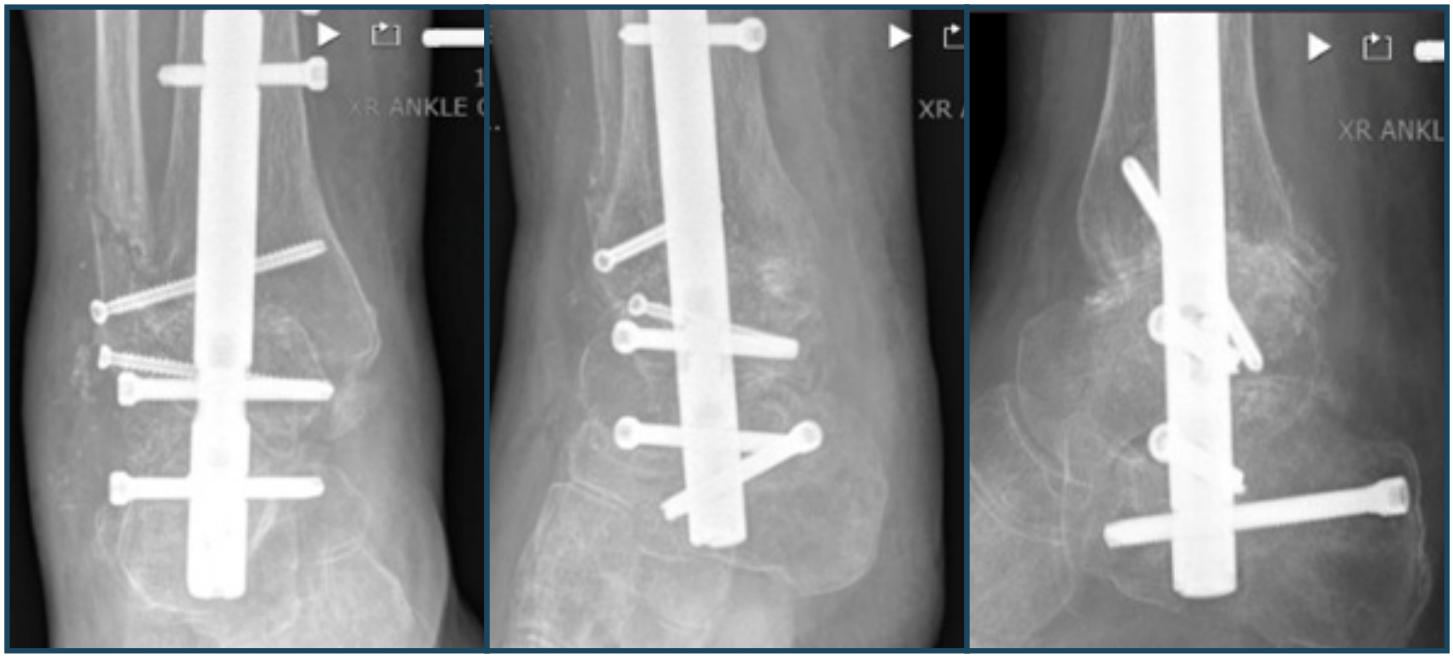

Figure 4: Tibiotalocalcaneal fixation following joint preparation: The ankle and subtalar joint have been fixated and compressed with a tibiotalocalcaneal intramedullary rod and independent screw fixation from the fibula to Tibia and Talus, showing bony apposition across the joint surfaces at time zero. The Cartilaginator™ assists in this process through contouring of the deformity on both the proximal and distal joint surfaces.

Midfoot joints:

The midfoot represents a complex of multiple different joints including the naviculocuneiform, intercuneiform, metatarsal cuneiform, and metatarsal cuboid joints. Approaches are therefore variable, and timeliness of joint preparation is paramount as often many joints are being prepared and fixed at once. The Cartilaginator™ can be introduced into the joints with minimal manual traction or using other distraction techniques as the surgeon prefers. The variety of tips that are available offer a range of choices that conform to any of the above-mentioned joints. The author prefers to use an open approach, however in higher risk and neuropathic patients an MIS approach is chosen.

Figure 5: Open approach to the NC joint, preparation with concave and convex tips.

Posterior heel / Achilles tendon:

We have found The Cartilaginator™ an easy means by which to perform a calcaneal ostectomy during surgery for a Haglund's deformity. The concave tip is used to rasp the calcaneus and remove the excess spurring, allowing the surgeon to create a smooth contour at the posterior tuberosity of the calcaneus. Additionally, use of the cutting tip is felt to minimize the risk of violating the neurovascular structures when contouring the deep portion of the calcaneus. This reduces the need for multiple saw blades or other sharp-tipped instruments and saves OR time and procedure cost.

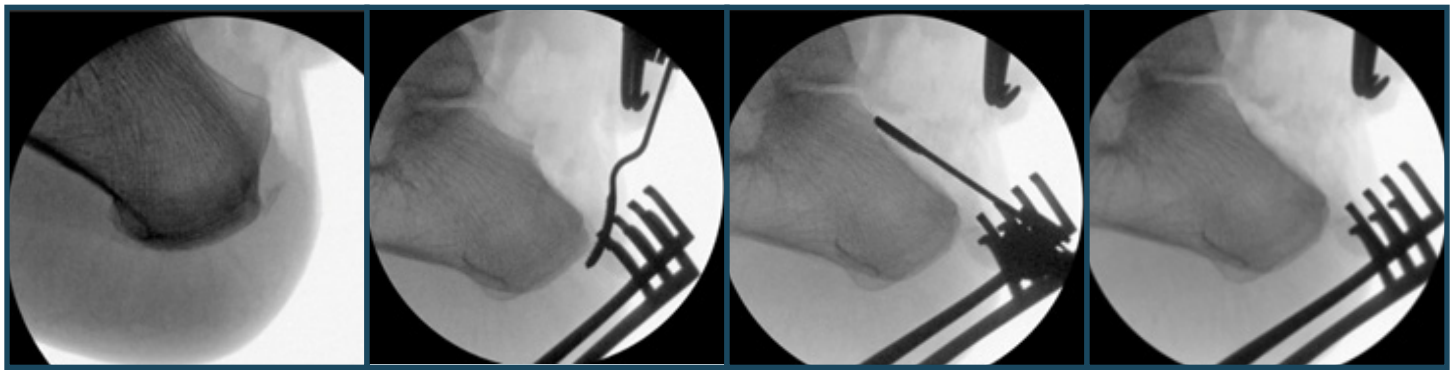

Figure 6: A Haglund's deformity being approached posteriorly. After removal of the Achilles enthesophytes with a knife, the concave and cutting tips of The Cartilaginator™ are used to contour the bone posteriorly (figure B) and also along the posterior facet leading to the subtalar joint.

1st Metatarsal:

The Cartilaginator™ can be used for an MIS Cheilectomy. Through a small (<1cm) dorsal incision, a cheilectomy can be performed using the concave tip. Fluoroscopy is used to verify the osteophyte has been removed. The great toe is then flexed and extended to determine if adequate range of motion was achieved through the post cheilectomy.

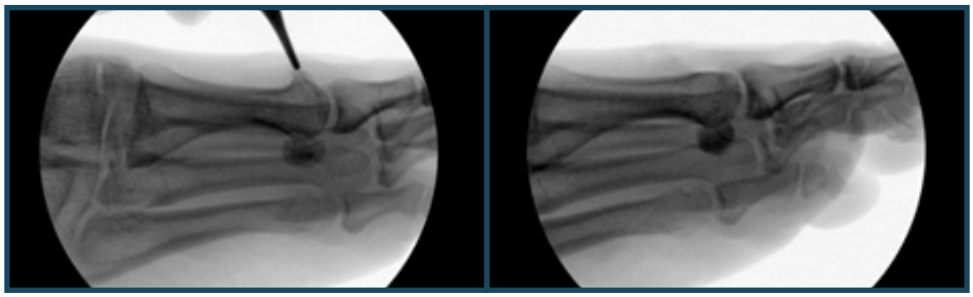

Figure 7: MIS Cheilectomy pre and post operative imaging. The Cartilaginator™ was employed for dorsal osteophyte resection through a small dorsomedial incision.

Nonunion/Malunion/Revision procedures:

The Cartilaginator™ can be used for both primary and revision surgery. The saw tip style or cutting blade is particularly valuable in these situations for removing osseofibrous tissue which accumulates from a nonunion and/or malunion (Figure 8). Following the use of the saw tip to open a sclerotic joint space (typical of a hypertrophic nonunion), the matching concave and convex joint preparation tools are then used to contour the two joint surfaces to matching concave/convex surfaces. This allows for compression of the tibiotalar joint space following joint preparation and fixation.

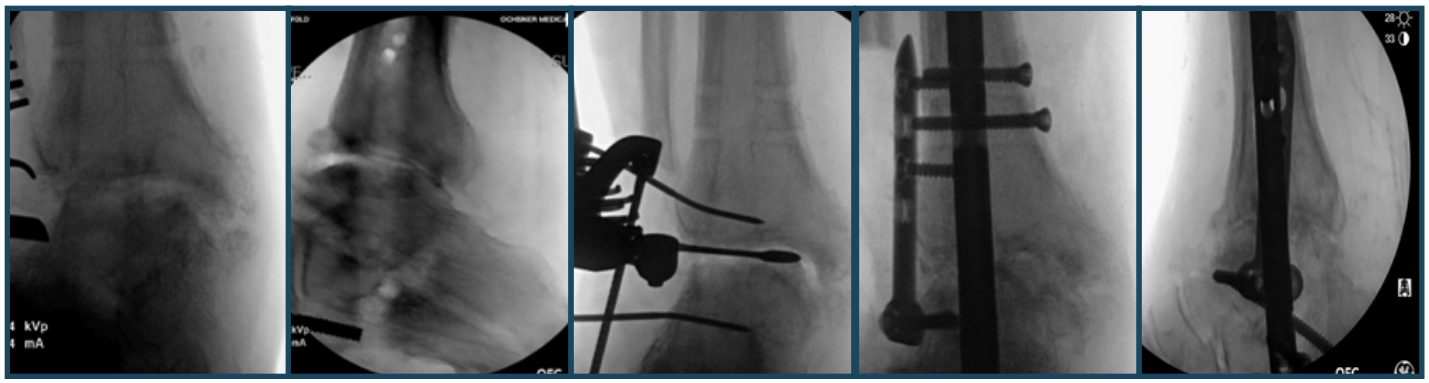

Figure 8: Fluoroscopic images demonstrating a tibiotalar nonunion, which is able to be quickly and accurately prepared using The Cartilaginator™ using the saw tip attachment. The same patient now status post Tibiotalocalcaneal arthrodesis with a plate and nail construct, showing matching bony surfaces on AP and lateral intra-operative fluoroscopic images.

Areas of further study:

One of the benefits of use of The Cartilaginator™ is decreased operative time versus traditional preparation techniques. Badell et al[ix] noted significant time savings with equivalent union rates in 47 joints (n=27) when using a power rasp versus traditional joint preparation techniques in subtalar, talonavicular, calcaneocuboid, and tarsometatarsal arthrodesis. The authors found that the use of a power rasp reduced the time and cost of joint preparation in all joints studied (subtalar, talonavicular, calcaneocuboid, and tarsometatarsal) without compromising union rates. Cost savings was calculated using the time measured intra-operatively by the surgeons multiplied by a generic dollar/minute estimate of OR time.

This may be less accurate than a more rigorous cost analysis such as Time Driven Activity Based Cost (TDABC) Analysis, which has been found to more accurately reflect costs for multiple different procedures in orthopedics.[xi] Also, the authors did not use matched concave-convex joint preparation techniques in this

study. The Cartilaginator™ offers a robust selection of tips available with different shape and sharpness, able to match the surfaces of both sides of the proposed arthrodesis.

Thermal necrosis is the phenomenon of in situ bone necrosis from excessively high tissue temperatures. This is a known risk factor during joint preparation with any heat producing device.[xii] Haddad et al studied the effect of continuous irrigation on arthrodesis, performing joint preparation using a high-speed cutting burr in 16 in vivo rabbit specimens. The authors found there was a trend towards decreased fusion rates and lower fusion mass in non-irrigated specimens.[xiii] More recently, Hall et al measured heat generation using three K-type thermocouples in four below knee cadavers testing heat generation from 2mm x 20mm Shannon burrs. They found average burr time, maximum heat generation and overall change in heat was 86.2 seconds, 102.4 °F and 78.9 °F for all trials.[xiv]

Theoretically, the low RPMS (40% using a Stryker system 9) should mitigate the risk of thermal necrosis from The Cartilaginator™. Similarly, the surgical technique including a "fanning" motion which involves maneuvering the hand over a larger surface area. This slower speed should limit heat generation and help dissipate heat by increasing surface area during joint preparation. However, further study is warranted to demonstrate The Cartilaginator™ does not generate thermal necrosis of tissue.

Conclusions:

The Cartilaginator™ can be employed in numerous locations for fusion throughout the foot and ankle, making it an excellent device for joint preparation and bone contouring. The multiple tip shapes allow for concave-convex joint preparation, allowing better compression and better bony apposition. This instrumentation offers potential cost savings via faster and more accurate joint preparation. Further study is warranted on the long-term outcomes of this tool and technique, but preliminary data suggests promising results in maximizing efficiency and precision in the operating room.

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MKT-170-00007 Rev A 04/2025