

## Trauma: Diet, Nutritional Supplements and Botanical Considerations

*In treating any tissue trauma, one must consider the patient's diet and recommend appropriate nutritional and botanical supplements that may promote and/or support the healing process. Inflammatory arthritis and degenerative arthritis are not addressed in this protocol.*

**Table I. Summary of Supplements for Musculoskeletal Trauma Treatment and Prevention**

Phase of Injury	Substance	Therapeutic Effects	Dose
Acute (1-14 days post injury)	Bromelain Chymotrypsin Trypsin	Anti-inflammatory	2000-9000 MCU/day bromelain (or equivalent); 1/3 dose between meals. For 5-14 days.
Acute	Citrus bioflavonoids, Curcumin	Anti-inflammatory	900-1800 mg/day: May be useful only before peak of inflammatory phase.
Acute	Proprietary enzyme/ flavonoid combinations (e.g. Wobenzym®)	Anti-inflammatory	3-4 tablets, 3-4 times per day at least 30 minutes before meals
Acute	Kava	General sedative effects; anxiety reduction	100 mg t.i.d. standardized kava
Acute, Chronic	Valerian	General sedative effects; treating insomnia	300-400 mg b.i.d. standardized valerian; for insomnia, 300-500 mg 1 hr before bedtime
Preventive	Fluids/electrolytes/ Minerals Vitamin E and/or Ginkgo	Prevention of muscle cramps due to a) fluid, electrolyte, or mineral imbalances; b) peripheral vascular disease	a) Increased fluid, electrolyte, calcium and magnesium intake b) Vitamin E, 600-1600 IU/day and/or Ginkgo biloba, 120 mg/day
Preventive	Vitamin C	Reduce symptoms of delayed-onset muscle soreness	400-3000 mg/day
Rehabilitative (after inflammation has subsided)	Broad-spectrum vitamin and mineral supplement	Tissue-healing support	At least 100% RDA or Daily Value of most ingredients
Rehabilitative	Vitamin C	Tissue-healing support	Up to 1000 mg/day
Rehabilitative	Zinc	Tissue-healing support	Up to 50 mg/day
Rehabilitative	Glycosaminoglycans (GAGs)	Tissue-healing support	Chondroitin sulfate, 1200 mg/day; glucosamine sulfate, 1500 mg/day
Rehabilitative	Bone-related nutrients	Fracture healing support	100% RDA or Daily Value of calcium, magnesium, vitamin D, phosphorus
Rehabilitative	Microcrystalline Hydroxyapatite Complex (MCHC)	Correction of delayed fracture union	Six grams daily

## Reducing Traumatic Inflammation with Proteolytic Enzymes: Acute Phase (1-14 days post injury)

Proteolytic enzymes may be considered an alternative to analgesics or NSAIDs in the control of pain and inflammation and may improve healing time. These enzymes are available as extracts from bovine pancreas (trypsin, chymotrypsin), pineapple stem (bromelain), or other sources.<sup>1</sup>

**Dose:** Generally, three to four tablets or capsules of enzyme concentrate three times per day on an empty stomach is a reasonable, practical dose. More specifically, for bromelain, current clinical authorities<sup>2-3</sup> suggest at least 2000 MCU<sup>†</sup> of bromelain per day up to as much as 9000 MCU per day. A therapeutic trial of 5-14 days is suggested, depending upon resolution of inflammation, re-injury, etc. Clinicians may use their own judgment to adjust these dosages based on body weight and patient response.

**Note:** Pharmaceutical-grade proteolytic enzymes used in clinical research were provided in enteric-coated tablets for protection through the upper GI tract.<sup>4</sup> While some practitioners feel that uncoated tablets are at least as effective, it is recommended that enteric-coated tablets be used whenever available.

**Rationale:** *The use of proteolytic enzymes in the treatment of musculoskeletal trauma and other inflammatory conditions*

<sup>†</sup> Proteolytic enzyme potencies are defined in milk-clotting units (mcu), gelatin-digesting units (gdu), United States Pharmacopeia (USP), or International Pharmaceutical Federation (FIP) units. While it is known that 1 gdu is equivalent to 1.5 mcu, it is unclear how conversions can be made between other units. Product labels indicate enzyme activity per gram of enzyme concentrate and activity per dose. For example, a product containing 200 mg tablets of 1800 MCU/gram bromelain provides 360 MCU per tablet. An equivalent number of milligrams of products with similar potency should be equally effective. (Bucci L. Nutrition applied to injury rehabilitation and sports medicine. Boca Raton, FL: CRC Press; 1995.)

*is based on two proposed mechanisms in which these enzymes augment the action of natural tissue proteases. First, they may reduce inflammatory response by causing the breakdown of inflammatory proteins that cause vascular permeability and pain. Second, they may significantly improve local circulation and reduce edema by breaking down cell debris and fibrin, facilitating their uptake by the lymphatic system.*

**Efficacy:** Absorption studies have demonstrated significant (though less than 40%) uptake of oral proteolytic enzymes through the gastrointestinal tract.<sup>5-6</sup>

Many studies have demonstrated the usefulness of proteolytic enzymes for various types of injury and inflammation.<sup>7-8</sup> The majority of these studies are divided equally between bromelain and trypsin-chymotrypsin, with comparable results. Prophylactic or post-traumatic treatment of athletes with proteolytic enzymes (bromelain or trypsin-chymotrypsin) resulted in fewer time-loss injuries and faster return to competition.<sup>9-16, 17</sup> Bromelain treatment of patients hospitalized for various injuries and inflammatory conditions resulted in 30% to 50% less time spent in the hospital than controls.<sup>18</sup> Treatment of lumbar disc prolapse patients with trypsin-chymotrypsin resulted in greater symptom reduction, improved straight leg raise, and decreased intake of analgesics compared to placebo.<sup>19-21</sup> In contrast, one trial found no effect of trypsin-chymotrypsin on the healing of sprained ankles; the reasons for these discrepant results are unclear.<sup>22</sup>

**Contraindications:** Clotting disorders or anticoagulation therapy, pre-surgical status, systemic infection, and allergy to food sources (i.e., pineapple, pork, beef, papaya).<sup>1</sup>

## Reducing Traumatic Inflammation with Flavonoids: Acute Phase

Flavonoids such as citrus bioflavonoids, curcumin, bilberry anthocyanosides, or oligomeric proanthocyanidins (OPC), from grape seed extract offer another option for control of pain and inflammation, although there is not as much evidence to support their use as there is for proteolytic enzymes. In fact, the usefulness of this therapy for *post-traumatic* musculoskeletal conditions is somewhat speculative.

Flavonoids are plant chemicals present in many fruits and vegetables, which have been found to possess pharmacologic activity.<sup>23</sup>

**Dose:** A standard dose of 900-1800 mg/day as citrus bioflavonoids has been used prophylactically in the three controlled studies that have been published.

Post-surgical application of curcumin was 1200 mg/day in one trial.

Bilberry anthocyanosides, 115 mg/day, have been given for 17 days beginning one week before surgery. (It may be difficult to obtain this amount of anthocyanosides from currently available products without taking several pills per day.)

The precise dose of grape seed extract used in a French study is unclear, but therapeutic doses usually range from 150-300 mg/day of OPCs.

**Rationale:** *These phytochemicals may significantly restrict vascular permeability to limit swelling<sup>24</sup> and may also inhibit inflammatory prostaglandins.<sup>25</sup> They may be useful only before the peak of the inflammatory phase as they have not been tested on established edema.<sup>26</sup>*

**Efficacy:** Citrus bioflavonoids have been used in two published control studies. In one study, prophylactic treatment of football players with citrus bioflavonoids and ascorbic acid, beginning with a loading dose of 1800 mg/day of each for one week and followed by 600 mg/day of each, reduced healing time of injuries suffered by the athletes by two-thirds.<sup>27</sup>

In another study, prophylactic treatment of athletes with citrus bioflavonoids, 900 mg/day, was judged superior to ascorbic acid alone or placebo, and no less effective than both bioflavonoids and vitamin C in combination. Observed benefits included reduction in recovery time by one-half, reduced incidence of muscle cramps, and minimal appearance of swelling, which disappeared rapidly.<sup>28</sup>

Postsurgical swelling, wound tenderness, and other complications have been reduced by curcumin, a plant pigment derived from turmeric, 1200 mg/day,<sup>29</sup> by bilberry extract delivering 115 mg/day anthocyanosides,<sup>30</sup> and by 300 mg/day of procyanidolic oligomers (PCOs) from grape seed extract.<sup>31</sup>

Other types of flavonoids, such as quercetin and pycnogenol, have not been studied for musculoskeletal trauma.

**Contraindications:** None reported.

## Enzyme/Flavonoid Combinations for Traumatic Inflammation

Many commercial products are available combining proteolytic enzymes of pancreatic and/or plant origin, and any of several flavonoids. These may offer a convenient alternative to single-ingredient products.

**Dose:** Typical effective regimens studied clinically use 10 or more tablets per day in divided doses between meals.

**Efficacy:** Several controlled and uncontrolled European studies,<sup>32 33 34 35 36 37</sup> though not others,<sup>38</sup> have shown the effectiveness of the combination formulas (Wobenzym<sup>®</sup> or Phlogenzym<sup>®</sup>) containing enteric-coated **proteolytic enzymes** of pancreatic and plant origin, and a derivative of the flavonoid rutin.

## Reducing Spasm/General Sedative Effects

For the purpose of this discussion, muscle spasm is defined as a protective contraction of muscles that have either been traumatically strained, or that cross a joint that has been acutely injured.

Oral supplements containing varying amounts of **calcium**, **magnesium**, and sedative herbs such as **valerian** and **kava** are popular treatments for muscle spasm, but no clinical research has validated their reported antispasmodic effects.

True magnesium or potassium deficiencies, as well as dehydration states, may result in a variety of symptoms, including generalized muscle spasms, and should be treated accordingly. Testing for these depletions is beyond the scope of this protocol. Calcium supplementation is not recommended for traumatic muscle spasm due to lack of evidence or convincing rationale.

When dealing with patients with musculoskeletal complaints, there may be additional benefits to the use of valerian or kava, which include their anxiety-reducing and/or sleep inducing properties. Patients suffering recent trauma may experience anxiety and troubled sleep related to their condition.

**Dose:** For treatment of anxiety, the dose is standardized kava (100 mg three times

a day [t.i.d.]<sup>39</sup> or valerian root extract (300-400 mg twice a day [b.i.d.]).<sup>40 41</sup>

These protocols may also reduce neuromuscular irritability due to the central nervous system effects of kava and valerian. For insomnia, the dose is 300-500 mg valerian one hour before bedtime.<sup>27 28</sup>

**Rationale:** *While both calcium<sup>42</sup> and magnesium<sup>43</sup> participate in cellular functions related to nerve transmission and muscle contraction, and subnormal serum concentrations of either produce symptoms of muscle irritability,<sup>44</sup> there is no direct relationship between dietary calcium intake and serum calcium concentration.<sup>45</sup>*

*Valerian has been shown to possess antispasmodic properties in an animal smooth muscle model as well as central nervous depressant activity,<sup>46</sup> including specific affinity to GABA-A and benzodiazepine receptors.<sup>47</sup> Many preparations containing valerian also contain passiflora. Passiflora, used in folk herbalism as a sedative, has never been the subject of an independent scientific evaluation of its effects and is rarely given separately.*

**Efficacy:** Human studies have found valerian to be effective in the treatment of insomnia and anxiety comparable to the benzodiazepines. Kava has also been found effective in the treatment of anxiety. No studies have been performed on the effectiveness of these products on muscle spasm.

## **Contraindications/Adverse Reactions**

**Kava:** Contraindicated in esophageal and gastrointestinal stenoses, intestinal obstruction, as well as pregnancy and lactation. It should not be used concomitantly with alcohol, barbiturates, or antidepressants. Allergic reactions are extremely

rare, but chronic use may lead to skin and eye changes.<sup>48-50</sup>

Use of kava supplements is currently controversial following numerous reports of hepatotoxicity in patients taking kava, although several authorities object that 1) cause and effect has not been definitively established, 2) these numbers represent a very small proportion of overall kava use in the world population, and 3) several clinical trials have been conducted for up to six months with no reports of hepatotoxicity.<sup>51 52</sup> However, it remains prudent to restrict kava recommendations to short-term use in patients with no history or risk of liver disease, who can be expected to avoid using alcohol concomitantly with kava. Screening patients after four weeks for elevated liver enzymes is also prudent.

**Valerian:** Adverse reactions noted in human clinical trials included headache, excitability, uneasiness, and cardiac disturbances, and some authorities speculate additive effects with other CNS depressants. Valerian was shown *not* to impair the ability to drive or operate machinery in one study,<sup>53</sup> and a case of overdose with 20 grams of powdered root produced no lasting adverse effects.<sup>54</sup> **Note: Not contraindicated during pregnancy or lactation.**<sup>55</sup>

**Magnesium:** Contraindicated in patients with renal failure.<sup>56</sup> Elderly patients may be at higher risk of hypermagnesemia (symptoms include hypotension and cardiac dysrhythmias) due to altered physiology, medication side effects, and use of magnesium-containing over-the-counter medications.<sup>57</sup> Large single doses may cause diarrhea.<sup>58</sup>

## Muscle Cramps

Muscle *cramps*, occurring without obvious trauma, may have nutritional or non-nutritional causes. Biomechanical causes, such as shortened muscles that are then overstretched, must be considered. Truly pathological causes, such as vascular insufficiency must also be ruled out.<sup>59 60</sup>

**Dose:** If dehydration or electrolyte loss is suspected, recommend increased intake of fruits, vegetables, and/or water. If low calcium or magnesium intake is suspected, recommend appropriate supplementation (600-1000 mg/day calcium; 200-400 mg/day magnesium). If peripheral vascular disease is suspected, recommend 600-1600 IU/day of **vitamin E**, or 120 mg/day of **ginkgo biloba extract**.

**Rationale:** *Leg cramps in exercising athletes can be caused by dehydration, so **water** intake should be increased if this is suspected. It should be recognized, however, that a subset of endurance athletes may be vulnerable to overhydration and resulting hyponatremia. Therefore, dehydration should be verified by evidence of body weight loss during endurance exercise with typical fluid consumption for that athlete.*

*Despite popular belief, mineral imbalances or deficiencies are considered unlikely contributors to muscle cramping.<sup>61</sup> Nevertheless, additional intake of **potassium, magnesium and calcium** may prevent impaired local circulation and increased irritability of muscle tissue in some cases.<sup>62 63</sup>*

**Efficacy:** Electrolyte or mineral supplements have not been investigated in rigorous trials for preventing muscle cramps. Older individuals with leg cramps caused by peripheral vascular disease have benefited from 600-1600 IU/day of **vita-**

min E,<sup>64 65</sup> or 120 mg/day of **ginkgo biloba extract**.<sup>66 67</sup>

## Preventing Delayed-Onset Muscle Soreness

Delayed-onset muscle soreness (DOMS) is a consequence of unaccustomed activity that may appear within 24 hours of strenuous exercise or work and can last for days.<sup>68</sup>

**Dose:** Vitamin C, 400-3000 mg/day

**Rationale:** *Oxidative stress mechanisms have been postulated as contributing to DOMS.<sup>69 70</sup> Vitamin C taken in gram amounts starting well before anticipated exercise has the best evidence for reducing symptoms of DOMS. Preliminary evidence suggests supplements of vitamin E, L-carnitine, or consumption of tart (sour) cherry juice may also be effective, but more research is necessary.*

**Efficacy:** 400-3000 mg/day of **vitamin C**, taken for several days prior to and after strenuous exercise, may substantially reduce the severity of DOMS according to some studies,<sup>71 72</sup> though not others.<sup>73 74</sup><sup>75</sup> Gram amounts of vitamin C started several days before anticipated exercise may be necessary for best results. A controlled trial combining 500 mg/day vitamin C and 1200 IU/day of vitamin E for 30 days reported no effect on symptoms of DOMS, but significant reductions of related strength loss.<sup>76</sup> In one placebo-controlled crossover trial, 12 fluid ounces of tart (sour) cherry juice, taken twice per day for eight days, reduced pain and strength loss following eccentric strength exercise.<sup>77</sup> A non-randomized, single-blind trial suggested that taking three grams L-carnitine daily for three weeks could reduce exercise-related delayed muscle pain.<sup>78</sup> Several other dietary supplements have been investigated with

disappointing results for preventing or alleviating DOMS symptoms; these include tests of vitamin E alone,<sup>79</sup> bromelain,<sup>80</sup> chondroitin sulfate,<sup>81</sup> creatine,<sup>82</sup> fish oils and soy isoflavones,<sup>83</sup> and topical<sup>84</sup> or homeopathic<sup>85</sup> arnica.

## Rehabilitative Phase (after inflammation has subsided)

Taking a **broad-spectrum vitamin-mineral supplement** and consuming a diet with adequate to generous **protein** content has been proposed as a practical recommendation to athletes recovering from traumatic injuries.<sup>86</sup> Oral cartilage extracts (e.g., chondroitin sulfate) or precursors (glucosamine sulfate) may provide tissue growth factors, but this has not been shown for human joint and muscle injuries.

**Dose:** The Recommended Dietary Allowances for vitamins and minerals are an adequate guide to evaluating vitamin-mineral supplements and should be the target for most nutrients. Higher doses of vitamin C (up to 1000 mg/day) and zinc (up to 50 mg/day) may have additional benefit.

Protein intake comparable to typical Western diets (1-1.5 g/kg body wt per day) is sufficient. Chondroitin sulfate, 1200 mg/day, or glucosamine sulfate, 1500 mg/day, are therapeutic doses used in humans for other musculoskeletal conditions.<sup>87 88</sup>

**Rationale:** *Regeneration of disrupted muscle and connective tissue requires the availability of appropriate protein and non-protein precursors as well as nutrient cofactors required by synthesizing enzymes.<sup>89</sup> Wound-healing research suggests that deficiencies of the following nutrients should be corrected to allow optimum tissue growth:<sup>90 91 92 93</sup>*

- *Calories, protein, essential fatty acids (deficiencies uncommon in Western diets)*
- *Vitamins A, B<sub>1</sub>, B<sub>2</sub>, C, pantothenic acid (deficiencies uncommon in Western diets)*
- *Zinc, copper, manganese, selenium (deficiencies more likely in Western diets)*

*Substantial trauma appears to increase requirements for protein (but still within typical Western intake) and vitamin C:*

*Animal studies have reported accelerated tissue healing with supplements of **vitamin A**,<sup>94</sup> and reduced post-traumatic adhesions with supplemental **vitamin E**.<sup>95</sup> <sup>96</sup> Controlled human research has found that **zinc** deficiency is associated with poor healing<sup>97 98</sup> and zinc supplements have been effective for reducing healing time of various tissue lesions in many,<sup>99</sup> <sup>100 101</sup> though not all,<sup>102 103</sup> studies.*

***Vitamin C** has long been known as an essential cofactor for collagen synthesis. Severe injury appears to increase vitamin C requirements,<sup>104</sup> and vitamin C deficiency causes delayed healing at all stages of healing.<sup>105</sup> Preliminary studies in humans suggest that patients can benefit from vitamin C supplementation in terms of faster healing times from a number of injury types, including minor injuries and skin wounds.<sup>106</sup> One report suggested that 500 mg/day or more of supplemental vitamin C helped many people avoid surgery for herniated intervertebral discs.<sup>107</sup> In vitro studies have reported that high concentrations of ascorbate in chondrocytes allow for optimal protein and proteoglycan synthesis.<sup>108 109</sup> Furthermore, reduced cartilage erosion and other pathological changes are found in*

*joint-injured animals given high doses of vitamin C.<sup>110 111</sup>*

*Several members of the **B-vitamin** family are important for optimum healing. Animal studies show improved healing when adequate amounts of vitamin B<sub>1</sub>,<sup>112</sup> pantothenic acid (vitamin B<sub>5</sub>),<sup>113</sup> and vitamin B<sub>6</sub><sup>114</sup> are present. Improved strength of healing skin wounds in humans has been recently shown using high doses of vitamin C and pantothenic acid.<sup>115 116</sup> Controlled research reports that a combination of at least 150 mg/day of vitamins B<sub>1</sub> and B<sub>6</sub>, along with 750 mcg/day of vitamin B<sub>12</sub>, reduces the amount and duration of anti-inflammatory therapy required for acute lumbar spinal pain episodes,<sup>117 118</sup> <sup>119</sup> and may help prevent relapses of spinal pain.<sup>120</sup>*

*Glycosaminoglycans (AKA, GAGs, proteoglycans, mucopolysaccharides, chondroitin sulfates, etc.) comprise the matrix component of most connective tissue and bone. They contain small amounts of protein, large amounts of specialized carbohydrates synthesized by chondrocytes, and some minerals.<sup>121</sup> Manganese is a required co-factor for some of the enzymes responsible for synthesizing proteoglycans.<sup>122</sup> Silicon also appears to play a role in connective tissue synthesis, according to animal studies.<sup>123</sup>*

*Glycosaminoglycans have been shown to be well absorbed in humans as both intact and broken down particles. They have been further shown to deposit into bone and joint tissues in animals. In vitro studies have shown exogenous glucosamine to be efficiently incorporated into connective tissue proteoglycans, resulting in enhanced production of these molecules.<sup>124-126</sup>*

***Chondroitin sulfate** (CS) and other GAG materials are available as supplements in the form of bovine trachea or shark fin*

extracts and mussel concentrates. These may supply important precursors for re-synthesis of disrupted connective tissue structures. The bioavailability of intact CS consumed orally in humans has been reported to be up to only 12%,<sup>127</sup> but additionally absorbed digestive breakdown products may account for a great deal more available precursors.<sup>128</sup> No clinical studies have been done to investigate the effect of CS on musculoskeletal injury healing, but *in vitro* studies have demonstrated that exogenous CS deposits into bone and joint tissues,<sup>129</sup> and stimulates proteoglycan production in human articular chondrocytes<sup>130</sup> and animal tissues.<sup>131</sup><sup>132</sup> (More information about using chondroitin sulfate may be found in the CSPE protocol, [Glucosamine and Chondroitin Sulfate](#).)

**Efficacy:** For disc disorders, Cox recommends a nutritional supplement containing manganese, calcium, potassium, magnesium, iron, zinc and mussel concentrate.<sup>133</sup> Although broad-spectrum vitamin/mineral supplements are widely used and there is anecdotal evidence for their use, to date no studies have been published on the effectiveness of nutritional supplementation in musculoskeletal rehabilitation. Similarly, no studies on the effectiveness of oral cartilage products in human tissue healing have been published. However, numerous animal and human studies have shown the effectiveness of topical or injected cartilage preparations on accelerating the healing of surgical and other wounds.<sup>134</sup> Furthermore, injected extracts have enhanced repair of osteoarthritic and traumatized cartilage and have been used to successfully treat patellar tendinitis. While the use of glucosamine, a precursor of glycosaminoglycans, for improving the healing process has been discussed on a theoretical basis,<sup>135</sup> no clinical studies have investigated this claim.

**Contraindications:** High doses of vitamin C appear to be safe, though diarrhea and abdominal cramping may occur in some patients.<sup>136-138</sup> Zinc at doses over 100 mg/day for several months may induce a copper deficiency<sup>139</sup> (preventable with co-administration of 1 mg/day copper<sup>140</sup>) and may impair immune responses.<sup>141</sup> Clinical studies using either glucosamine sulfate or chondroitin sulfate report no significant side effects when compared with placebo.

## Fracture Healing

In addition to controlling the inflammation associated with traumatic fracture, the unique reparative processes of bone may benefit from consideration of nutrients specific for both connective and bone tissue proliferation. **Microcrystalline hydroxyapatite (MCHC)**, a special preparation of veal bone, may be helpful in cases of delayed union.

**Dose:** A broad-spectrum vitamin-mineral supplement with increased dietary **protein** intake can be justified based on the discussion above, under "Rehabilitative Phase." Additional **calcium, vitamin D, phosphorus** and **magnesium** to achieve RDA or 100% Daily Value levels are also recommended. In cases of delayed union, six grams per day of microcrystalline hydroxyapatite is recommended until successful union is demonstrated.

**Rationale:** *Nutritional considerations for tissue healing discussed above probably apply as well to the management of fractures, although research is limited. Due to the mineral content of bone, adequate dietary calcium, vitamin D, phosphorus and magnesium may also be important, but no trials have investigated supplementation with these nutrients to increase fracture healing.*

*Animal studies suggest that fracture healing may be accelerated by supplemental **vitamin D**<sup>142</sup> and **zinc**.<sup>143</sup>*

*MCHC supplementation may be an improvement in the nutritional support of bone healing according to both animal and human research.*<sup>144 145</sup>

**Efficacy:** Elderly patients hospitalized with hip fractures required shorter stays for rehabilitation or other reasons when given 20 grams/day of supplemental **protein** in controlled studies.<sup>146 147</sup>

**MCHC** is prepared from veal bone by fat extraction and low-temperature grinding. The product retains all of the minerals, proteins, and glycosaminoglycans of the original source tissue. Calcium absorption appears to be superior from this compound than from traditional sources of supplemental calcium.<sup>148</sup> One report exists of promising results in placebo-controlled human studies using MCHC to facilitate fracture union both in older patients and in cases of delayed union.<sup>149</sup> Six to nine grams per day is a typical therapeutic dose used in MCHC research.<sup>148 149</sup>

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