

REPORT

Silicon: An Overlooked
Trace Mineral

Silicon, an abundant trace mineral in nature is proving to be an essential ingredient for stronger bones, better skin and more flexible joints. Including silicon in your diet may boost the benefits of calcium, glucosamine and vitamin D. Here are some of the latest findings on this overlooked mineral.

The human body contains approximately 7 grams of silicon, which is present in various tissues and body fluids. The silicon in tissues is usually bonded to glycoproteins such as cartilage, whereas the silicon in blood is almost entirely found as either free orthosilicic acid or linked to small compounds.

The biological requirement for silicon was first demonstrated by Edith Carlisle and Klaus Schwarz^{1,2} in experiments with rats and chickens that were fed silicon-deficient diets. These experiments demonstrated that nutritional silicon deficiency causes skeletal deformities such as abnormal skull and long bone structure, as well as poorly-formed joints with decreased cartilage content. Detailed biochemical analysis revealed that silicon is an essential nutrient for the structural integrity and development of connective tissue.^{3,4} Silicon's most popular use is as a nutritional supplement to strengthen not only the bones and connective tissues, but also hair, nails and skin.

Silicon in tissue and joints

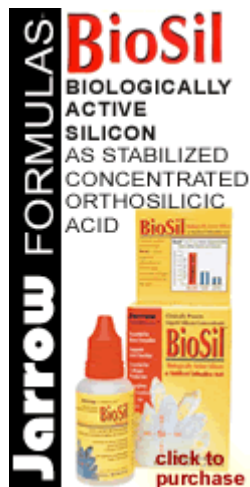
Connective tissue is composed of cells which produce the fibrous protein matrixes of collagen and elastin, as well as the hydrated (water retaining) network of amino-sugars called glycosaminoglycans (GAG) or muco- polysaccharides (MPS). Silicon is believed to stabilize the glycosaminoglycan network.⁵

The amino-sugar glucosamine, which is also needed for the biosynthesis of GAGs, has been clinically proven to be effective in the treatment of arthritis.⁶ Given silicon's chemical association with GAGs, it seems that the combination of both glucosamine and silicon could have a complementary therapeutic value in the treatment of arthritis and other related connective tissue diseases.

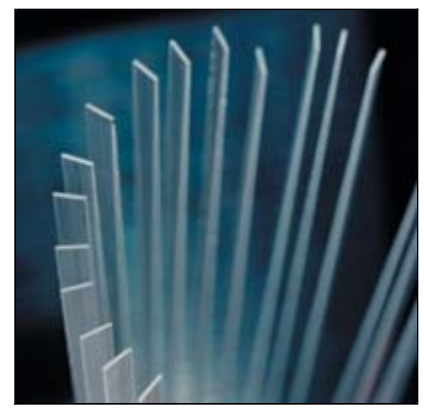
Silicon, bone and osteoporosis

Bone is actually a special type of connective tissue. Silicon is a major ion in osteogenic cells, which are the bone-forming cells in young, uncalcified bone. As the bone matures, the silicon concentration declines and deposits of calcium and phosphorous are formed simultaneously. In other words, the more "mature" the

bone tissue, the lower the silicon concentration in the bone. Therefore, it has been concluded that silicon acts as a regulating factor for the deposition of calcium and phosphorous in bone tissue.⁷ Silicon's regulatory action in bone calcification and its vital role as a structural component of connective tissue are the reasons for silicon's classification as an essential trace element in animal and human nutrition.



Silicon plays an ongoing role in maintaining bones after their formation. Bone is a dynamic, living tissue system that balances bone formation by osteoblast cells and the ongoing reabsorption of bone tissue by osteoclast cells. (Bone minerals are dissolved and organic bone matrix components such as collagen are digested by the action of of osteoclast cell.) Osteoporosis occurs when there is a low rate of bone formation and a high rate of bone reabsorption, thus leading to a decline in bone mineral density and a decreased mechanical strength of the bone. Bone loss occurs generally with aging, but a clear acceleration occurs during menopause or following a failure or removal of the ovaria, which leads to estrogen deficiency.



Closeup of silicon cluster

Studies with animals indicate that silicon supplementation reduces the number of osteoclast cells, thus partially preventing bone reabsorption and bone loss.⁸ On the other hand it was shown in vitro that silicon compounds stimulate the DNA synthesis in osteoblast-like cells.⁹ Animal models for osteoporosis using estrogen deficient rats demonstrate that silicon supplementation can prevent bone loss.¹⁰ In a clinical study of 53 osteoporotic women, silicon supplementation was associated with a significant increase in the mineral bone density of the femur.¹¹ The positive results of these studies suggest that silicon supplementation, along with calcium and vitamin D, may be useful in the fight against osteoporosis.

Silicon's other uses

In addition to connective tissue and bone health, several other promising health benefits of silicon, such as protection against aluminum toxicity and protection of arterial tissue have been reported.



As much as aluminum has been found in brain lesions of Alzheimer's patients, several researchers have suggested that aluminum toxicity may be involved in the pathology of Alzheimer's disease and other neurological disorders. In studies with rats,¹³ silicon was found to prevent the accumulation of aluminum in the brain. It is believed that silicon bonds with aluminum in food and beverages, thereby reducing the gastrointestinal absorption of aluminum. The protective role of silicon against aluminum was also confirmed in a French population study of elderly subjects: high levels of aluminum in drinking water had a deleterious effect upon cognitive function when the silicon concentration was low, but when the concentration of silicon was high, exposure to aluminum appeared less likely to impair cognitive function.¹⁴

BENEFITS OF SILICON

Atherosclerosis is a condition characterized by the formation of plaque in the arteries. Plaque is formed when damaged artery tissue is not properly repaired,

Joint

- Silicon was shown to be essential for the formation of articular cartilage.
- Silicon is a cross-linking agent in the glycosaminoglycan network which attracts and hold water in the joint.

Bone

- Silicon acts as a regulating factor in bone mineralization.
- Silicon stimulates DNA synthesis in osteoblast-like bone forming cells.
- Silicon inhibits osteoclast mediated bone reabsorption in vitro.
- The synthesis of collagen, the fibrous protein which is essential for the flexibility of the bone, is decreased by Silicon deficiency.

Tendons and ligaments

- The synthesis of collagen, a major compound in tendons and ligaments, is decreased by Silicon deficiency.
- The activity of prolyhydroxylase, a specific enzyme for collagen synthesis, was shown to be Silicon dependent in vitro.

Heart

- Silicon makes the inner lining of arterial tissue (tunica intima) less permeable. In the case of a high cholesterol diet, Silicon supplementation reduces the occurrence of arteriosclerotic lesions in blood vessels.
- The aorta and the carotid artery of healthy persons contain approximately 10 times more Silicon compared to atheromatous arteries.

Skin

- Silicon is important for optimal collagen synthesis.
- Silicon is crucial for activating the hydroxylation enzymes for crosslinking collagen, which improves the strength and elasticity of this fibrous protein. Better collagen means better skin, more elasticity and fewer wrinkles.

thus allowing scar tissue, oxidized cholesterol and other materials to obstruct the normal blood flow.

Experiments with rabbits fed a high-cholesterol diet demonstrated that supplementation with silicon protected the rabbits from developing arteriosclerosis. Aside from protection against arteriosclerosis, silicon is a vital structural component of arteries. However, the silicon concentration of arteries declines with age, most likely increasing the risk of lesions and plaque formations.^{15,16}

Silicon in your diet

The daily dietary intake of silicon is estimated to be between 20 to 50 mg,¹⁷ with lower intakes associated with animal-based diets and higher intakes associated with vegetarian diets. Plants absorb orthosilicic acid from the soil and convert it into polymerized silicon for mechanical and structural support.¹⁸ This explains why fiber-rich foods such as cereals, oats, wheat bran and vegetables have a high silicon concentration. An unbalanced diet with a limited supply of vegetables, fruits and cereals will be low in silicon concentration.

While whole grain foods are a good, natural source of silicon, the silicon from these foods is insoluble and cannot be directly absorbed in the gastro-intestinal tract. Silicon in food is solubilized by stomach acid into orthosilicic acid, which absorbs directly through the stomach wall and the intestine into the blood. Lower stomach acidity, whether due to illness or age, diminishes our ability to metabolize silicon from food sources. Aging is reported to be associated with an increasing gastric pH. In this view elderly people will have a decreased capacity to convert dietary silicates into bioavailable orthosilicic acid. The refining and processing of food, which removes silicon-containing fibers, contributes to a lower dietary silicon intake. Additionally, many of the additives used in the food industry interfere with the uptake of silicon. In fact, these additives can (a) increase the gastric pH and thereby decrease the rate of hydrolysis of dietary silicates, (b) promote polymerization of orthosilicic acid and (c) chelate minerals in general which are then eliminated through the intestinal tract without absorption. The extensive re-use of soils and the application of aquacultures minimize the essential supply of orthosilicic acid to plants. The resulting crops have a less rigid structure due to decreased biosynthesis of phytolytic fibers and specific epidermal cells which contain silica structures. Consequently these crops will have a lower silicon concentration and contribute less to the dietary silicon intake compared to crops which have been cultivated on a natural, mineral rich soil. Given all these factors, it is not surprising that silicon supplementation may be useful for a complete and balanced diet.

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Hair

- The outer shaft of hair, that provides elasticity and strength, is rich in Silicon. Hair with higher Silicon content tends to fall out less and has more shine and luster.

Nails

- Silicon is one of the predominant minerals in nails. A sign that Silicon may be systematically deficient is brittle and soft nails.
- Silicon improves the nail quality which results in a better protection against nail infections.

Mucosa

- Silicon restores mucosa in the respiratory tract in case of dehydration.

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Bioavailability and efficacy of silicon supplements

When selecting a silicon supplement, the most important considerations should be safety and bioavailability. (Bioavailability is a complex term for the degree of absorption and the biological response to the silicon compounds which are present in the product.) Organic silicon compounds, which are laboratory synthesized, contain silicon-carbon bonds. These molecules are normally not present in biological systems and can be very toxic. For this reason it is safest to use silicon compounds that are already present in nature or compounds that are the derivatives of natural products. Common silicon supplements include:

Plant extracts:

Bamboo and algae usually have high silica concentrations. However, plant extracts are often not standardized and the silicon concentration in these products varies greatly. As the silicon from plant extracts cannot be absorbed directly through the stomach wall, the bioavailability of these products requires high stomach acidity in order to produce soluble orthosilicic acid.

Colloidal silicon gel:

These products offer large, insoluble, polymer molecules of silicic acid suspended in water. Like plant extracts, these polymer-molecules cannot be absorbed directly through the stomach wall and therefore have a low rate of absorption. The stomach's ability to produce soluble orthosilicic acid is also limited to low concentration levels due to orthosilicic acid's limited stability.

Stabilized orthosilicic acid:

Now on the market is a liquid, stabilized orthosilicic acid concentrate. A research group from the University of Antwerp in Belgium has published a supplementation study describing a high rate of silicon absorption from a liquid silicon supplement containing 2% silicon in the form of stabilized orthosilicic acid. In the six-month study with calves, the total dietary silicon intake was increased by only 5% in the form of stabilized orthosilicic acid. Even with such a small dose of orthosilicic acid, the supplemented group showed 70% higher blood silicon levels than the unsupplemented group. These higher silicon blood levels also translated into a 12% higher collagen concentration in the skin of supplemented animals compared to unsupplemented animals. This study clearly demonstrated that the bioavailability of stabilized orthosilicic acid concentrate is very high compared to dietary silicon.¹⁹

THE COMPOSITION OF SILICON

The slow and lengthy process of soil erosion breaks down rocks into clay and loam; eventually the silicates react with water to form soluble silicon molecules. These soluble silicon molecules are called orthosilicic acid or monomeric silicic acid. Orthosilicic acid is the natural water soluble compound present in sea water, drinking water and other beverages such as beer. However, natural

Two independent Belgian research groups demonstrated both in a comparative human study that the total silicon absorption by the human body is considerably higher (more than 2.5 times higher) after supplementation of stabilized orthosilicic acid (as present in a product called BioSil™) compared to plant extracts or colloidal supplements. In fact, only BioSil™ supplementation resulted in a statistical significant increase in silicon absorption compared to the placebo. Without exception, each test subject had a similar absorption from orthosilicic acid, whereas large differences among subjects were found for the other silicon supplements.^{20,21}

The bone stimulatory properties of silicon was recently investigated in an extended study on chicks. For the first time a normal diet was used instead of silicon deficient diet, which made it possible to observe the superior biological action of silicon in supplemented chicks compared to a control group. The silicon was added to the drinking water of the chicks, which increased the total dietary silicon intake less than 0.5%. Despite this extremely low dose a significant effect was found on both the calcium concentration in the blood and the density of thigh bones (femura).

In fact, the chicks had, after six weeks supplementation, 5.6% higher bone density in the hip region and 4.25% higher bone density at the midshaft of their thigh bones compared to non-supplemental chicks. These results show clearly that stabilized silicon (choline-silicon complex) was able to stimulate the bone formation machinery resulting in a higher density.²²

mineral water has extremely low concentration levels of orthosilicic acid (0.1-1.0 parts per million) due to the molecule's limited stability. Attempts to increase the concentration of orthosilicic acid in mineral water result in

Based on all the current research, silicon is now being considered a critical nutrient to better manage the effects of age on the body. Increasing the silicon in your body can occur through foods, plant extracts or supplements. Those with osteoporosis should especially consider the benefits of consistent silicon intake.

References

the linking of several small orthosilicic acid molecules into larger, insoluble polymer-molecules. This so-called polymerization of orthosilicic acid occurs also in plants where the silicon fibers are important for the mechanical strength and flexibility of the plant. Silicon accumulating plants such as bamboo are characterized by a strong but flexible structure, whereas silicon deficiency in soil and plant tissues results in weakened mechanical strength.



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