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Mini-Review

Will the Elderly Benefit from a Fruit and Vegetable Nutritional Program? The Case of Vitamin C and Bone Health

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Abstract

Fractures and their causative and repair mechanisms have been topics subject to various forms of investigation for several decades. In both instances, and as populations age, preventing and treating bone fractures and a possible role for vitamin C in both these processes has received increasing attention in the recent literature, but with little mainstream practice application. This mini review examines whether vitamin C is of potential relevance in preventing osteoporosis and future fractures as well as in fostering fracture healing. A narrative review of the related literature housed in key data bases over the last five years and others is provided to support further investigation of this topic, and the recommendation for ensuring aging adults have sufficient access to fruits and vegetables containing vitamin C. Findings support both issues.

Background

Bone diseases such as osteoporosis, a debilitating chronic bone disease, along with fractures, especially those that do not heal optimally, remain important causes of excess morbidity and premature disablement, not only among independent community based older adults, but especially among those who are institutionalized,

despite years of effort to prevent bone loss and its associated debilitating consequences. Often associated independently or collectively with lifestyle factors, corticosteroid therapy, unintended injury, and a genetic predisposition to bone fragility and frailty, ascorbic acid or vitamin C has historically been linked to bone health status for some time. Yet, despite quite a consistent wealth of favorable evidence, its applied utility has not been well established in the context of either osteoporosis prevention or treatment, nor in the realm of fracture healing or prevention, when compared to the guidelines concerning calcium and vitamin D and the extensive research undertaken in this regard.

This lack of attention to vitamin C, given the observed role of vitamin C in various bone development and maintenance processes, plus its role as an anti-oxidant that can improve fracture healing [1] among other skeletal functions [2] is likely to be an important oversight to reconsider in the process of seeking strategies to foster bone health, especially among the elderly who may be highly susceptible to premature death and disability consequent to fracturing a hip and/or other bones. On the other hand, vitamin C arguably plays a pivotal role in fostering optimal skeletal health across the lifespan, including its favorable influence on collagen formation and normal bone development [2] and bone mineralization. By contrast, a deficiency in vitamin C, an essential micronutrient found predominantly in fruits and vegetables, potentially influences growth plate and bone trabeculae status, bone resorption processes, epiphyseal collagen synthesis and osteoblast differentiation, as well as bone density [2]. Other evidence in favor of a crucial skeletal role for vitamin C is its ability to retard age associated bone mineral density loss rates, along with its ability to foster better outcomes of hormonal treatments designed to improve bone density [2]. Vitamin C may also impact general health status, as well the recovery phases of a fracture quite favorably, while lowering the risk of older people for developing osteoporosis and/or bone fractures.

In particular, several important observations depicting the relationship and identified impacts of vitamin C outlined in Box 1 have shown that relative to reducing osteoporosis prevalence and severity, plus fractures in these and other at risk groups, past research appears to have provided tentative support for the idea of fostering adequate vitamin C intake in adult populations as a whole, but especially among aging adults. Since not all findings support a consistent bone vitamin C favorable relationship in the context of bone health and fracture prevention [3], however, for example this idea is disputed by Leveille *et al.* [4], and Ekrol *et al.* [1] this mini review was designed to examine recent work in this area in an effort to provide a balanced analysis at whether more research towards examining vitamin C and its clinical implications for fostering bone health is warranted.

- Deficiency leading to scurvy produces bone pain [5]
- Deficiency compromises bone health [2] and may lead to bone disorders [5]
- Sufficiency is positively implicated in bone metabolism [5]
- Critical moderator of collagen production [5, 6]
- Can regulate bone-based gene transcription [5]
- Can reverse bone loss of osteoporosis in animal model [7]
- Sufficiency may delay osteoporosis and fracture development [5, 8, 9]
- Positively correlated with bone mass [3] and bone mineral density [8]
- May reduce risk of complex regional pain syndrome after fractures [10]

- Is an important intrinsic mechanism for optimizing osteoclastgenesis and osteoblastgenesis [2, 9]
- High total vitamin C intake fosters decreases in bone mineral density loss
- Low or non-ascorbic acid diets yield reduced bone calcium and hydroxyproline contents [11]

- Deficient levels of vitamin C may foster spontaneous fractures, impaired bone growth and healing [5]

Box 1: *Past Findings in Support of a Positive Role for Vitamin C in Fostering Bone Health and Bone Healing*

That is, this mini review examines the status of the literature concerning bone health and the prevailing consensus of whether this can be mediated or moderated by vitamin C in some way, for example by following daily nutrition requirements for this compound and making key vitamin C containing fruits and vegetables available to the elderly, rather than failing to do this.

Aims

The specific purpose of this mini-review was to carefully examine the research findings documented over the past five years, along with the overall science-based knowledge in this realm to ascertain if this potential osteoporotic and fracture prevention strategy is likely to be more efficacious than not, given the knowledge humans are unable to synthesize vitamin C, which must constantly be restored [6].

Since fractures continue to prove highly prevalent, as well as disabling, and osteoporosis itself can lead to considerable life-long disablement in its own right, especially among older persons, it appears important to continue to examine the evidence base other than calcium and vitamin D as having a possible clinically important role in preventing osteoporosis and for advancing fracture healing where this has occurred.

Simultaneously, we hoped to propose salient lines of endeavor for future research and practice in this regard, including preventive practices against fractures and primary or secondary osteoporosis that are cost-effective, as well as safe, and may foster natural healing processes, and others.

Methods

To achieve the goals of this report, the present search strategy employed the search terms Vitamin C/Ascorbic Acid and Bone Health, Vitamin C/Ascorbic Acid and Fracture Healing, Vitamin C and Frailty, as key words, first for all available articles on the topic, and then for those more specific to the time period Jan 1, 2014-Jun 7, 2019 in the PUBMED, Science Direct, Scopus, Web of Science, and Google Scholar data bases. Other databases explored were: Embase and Academic Search Complete. To provide some clarity as to whether there is clinical evidence that vitamin C can either minimize osteoporosis risk, as well as fracture risk directly or indirectly, articles that addressed these issues were selected and downloaded. As well, those discussing the bone healing process, whether published in the realm of basic or clinical studies, were deemed valid. In addition to stand alone full length research reports, systematic reviews were deemed acceptable. No abstracts or foreign non-English articles were analyzed, however, and no restrictions were placed on the nature of studies, nor on the health status, or age or gender of the subject.

After completing a comprehensive scan of the relevant literature, salient references as well as those cited in some texts were selected for further reading and discussion. With no substantive well-designed studies on any of the above topics, especially in the realm of the specific topic of vitamin C and its relationship to preventing osteoporosis, or fostering fracture healing, only a narrative review was deemed suitable. However, by including the most up to date findings on this topic, plus an overview of prior work on vitamin C in the context of bone health, a broad picture of the state of the art regarding the topic of this review was anticipated.

To this end, relevant articles that were downloaded were scrutinized and the discussion below first outlines some general findings, followed by some specific clinically relevant observations. An attempt was made to categorize findings as either supportive of a possible beneficial fracture-vitamin C link, versus a non supportive or contrary view, bearing in mind negative studies are less likely to be published than positive studies.

For consistency the term vitamin C was adopted to describe the various aspects of related research as opposed to the lesser used and older term Ascorbic Acid, and it was decided not to focus on cellular or animal model studies in this effort, or those published prior to 2014 given the problem in translating these data to the current clinical realm. Other than that, it is believed this ensuing review examined almost all, if not all currently relevant clinical studies and reviews on the topic of vitamin C and bone health along with fracture healing, and related issues published in peer reviewed English journals. For a summary of prior studies readers are referred to the 2018 review by Malmir *et al.* [7]

Results

General Observations

As an example of the state of the literature on the present topic since 1980, Table 1 below depicts the relative number of related topical publications over time, as well as the number specifically for the periods January 1, 2014 - June 7, 2019 listed in PUBMED. As shown, vitamin C, bone osteoporosis and bone healing are highly studied topics, when viewed independently, yet very few past as well as current studies are housed in

this leading National data base, which can be taken as a fair representation of the best work in the field of examining vitamin C and bone interrelationships.

Table 1: *Table Depicting PUBMED Search Terms and Their Relative Results Vis a Vis the Current Topic 1980-2019*

Key words	Total number of reports 1980-2019	Number of reports Jan 2014-June 2019
Vitamin C	62573	10141
Fracture healing	25166	6373
Bone healing	52772	13700
Osteoporosis	84026	20162
Vitamin C + fracture healing	37	7
Vitamin C + bone healing,	94	24
Vitamin C + osteoporosis	225	40
Vitamin C + fracture prevention	64	19
Vitamin C + osteoporosis prevention	70	16
Dietary vitamin C + fracture prevention	24	6
Dietary vitamin C + osteoporosis prevention	49	10
Dietary vitamin C and bone mineral density	105	26

Specific Research Observations

As outlined above, and despite a plethora of studies on several individual topics listed above, there are clearly very few contemporary clinically oriented studies focusing on the implications of vitamin C as related to fracture healing and fracture prevention. These related studies and their methods, premises, substrates, durations, and outcomes assessed are however, reported below.

Among these recent studies, Malmir *et al.* [7] who conducted a systematic review to examine vitamin C intake in the context of osteoporosis and hip fracture risk found greater dietary vitamin C intake was associated with a 33% lower risk of osteoporosis (overall relative risk=0·67; 95% CI 0·47, 0·94). Greater dietary vitamin C intake was also associated with a lower risk of hip fracture and osteoporosis, as well as higher bone mineral density at femoral neck and lumbar spine sites. However, there was significant heterogeneity in the reviewed studies, important studies may have been omitted, and most that were examined were cross-sectional in nature. As well, some studied osteoporosis as an outcome, others fractures, and a further series were examined in terms of bone mineral density over follow up periods ranging from 4-20 years. Diet history and recall or food record questionnaires, which may have questionable reliability and validity, were commonly used to the exclusion of other methods of assessing vitamin C status in almost every reported study designed to assess bone outcomes relative to dietary vitamin C exposure. Finally, many studies (20/24) focusing on vitamin C intake and bone mineral density and fulfilling the study inclusion criteria were excluded from the meta-analysis, as were 7/13 examining vitamin C and fracture risk and ¼ examining vitamin C and osteoporosis risk.

Chin *et al.* [12] who similarly assessed the current evidence of the bone-sparing effects of vitamin C as derived from cell, animal and human studies, found cell-based studies to show that vitamin C is able to influence osteoblast and osteoclast formation, in a dose dependent manner where both high doses of vitamin C, as well as low doses might impair bone health. On the other hand, they stated vitamin C supplementation prevented bone loss in several animal models of bone loss, and that human studies generally showed a positive relationship between vitamin C and bone health. As indicated by the effects of vitamin C on bone mineral density, fracture probability and bone turnover markers, this group suggested that the relationship between vitamin C and bone health could be U-shaped, more prominent in certain subgroups, and different between dietary and supplemental forms. Unfortunately, as outlined above, most of the reviewed studies were observational, and thus could not confirm causality. Moreover, the one clinical trial that was reportedly performed was not a randomized controlled trial, thus confounding factors could not be excluded in explaining the study results, and despite related findings that vitamin C can exert highly beneficial effects on bone as well as bone stem cells [13].

A further summary report [5] that examined results of several epidemiological studies and others and that showed vitamin C to consistently have a positive effect on bone health was similarly inconclusive because the human studies examined were limited in design, were unable to show changes in bone status over time, and vitamin C was inconsistently measured. In addition, instruments used for assessment were also a major concern, because outcomes were based largely on surveys, rather than objective measures. Another issue was that the skeletal sites selected for examining bone mineral density were not necessarily comparable across studies or consistent within the skeletal profile of the individual.

Sun *et al.* [14] observed that dietary vitamin C intake can arguably lower the risk of acquiring a hip fracture among older adults, even though other supplements may play an additionally favorable role in this regard, and the fact other bone sites may respond differently. A related study by Kim *et al.* [15] who similarly found dietary vitamin C intake was positively associated with bone mineral density among postmenopausal women, and that an inadequate vitamin C intake could increase the risk of osteoporosis tended to support the observations of Sun *et al.* [14], but the sample was limited and excluded younger women and men. As well, the significant association between vitamin C intake and bone mineral density was only observed in subjects with a vitamin D deficiency aged 50-59 years or >70 years.

In other related research, while positive effects of fruit or vegetable intake on bone do not always point to a specific role for vitamin C [eg 16-18], Liu *et al.* [19] who reported greater fruit intake was independently associated with better bone mineral status among Chinese elderly men and women, further suggested that this finding was probably associated in part to the related dietary vitamin C intake, but this was not studied directly.

In an analogous study, Torbergsen *et al.* [20] who strove to examine micronutrients other than vitamin D and K on bone fracture risk and turnover showed low vitamin C among other factors was independently associated with an increased hip fracture risk, possibly through it effect on bone turnover mechanisms. This case control study, which employed acceptable outcome measures and a sample of 116 patients admitted for hip fracture and 73 home dwelling non fractured controls, while supporting the importance of ensuring older adults intake adequate vitamin C levels, was not a prospective study.

Kim *et al.* [21] who examined the relationship between nutritional intake and bone mineral density (BMD) in 189 postmenopausal Korean women using dietary intake via and bone mineral density T-scores measured at the lumbar spine, femoral neck and total hip using dual-energy X-ray absorptiometry did find vitamin C intake was positively associated with the femoral neck T-score, and the total hip T-score. Vegetable intake and its frequency which showed a positive association with the femoral neck and total hip T-scores led the authors to conclude vitamin C among other nutrients is positively associated with bone mass.

However, in the study by Finck *et al.* [3] which included men and women along with objective assessments of plasma and dietary vitamin C intake levels, only data from men showed an association between bone ultrasound measures and reduced fracture risk relative to higher vitamin C intake. Moreover, this group found dietary vitamin C had no association with either hip or spine fracture risk. Again, this was an observational study with less than precise ultrasound estimates of bone, and vitamin C intake over time was not assessed, along with other confounders such as sunlight exposure, fracture type, severity, and cause, vitamin D and calcium intake.

Melaku *et al.* [22] who similarly assessed the association between nutrient patterns and bone mineral density among 1135 subjects in an ageing Australian population, median age, 62.0 years, only measured dietary intake via a food frequency questionnaire. According to these data, plus bone mineral density outcomes, it appeared mixed-source dietary patterns may help to prevent losses of bone mineral density in similar subjects, but the specific role of vitamin C intake in this study was difficult to discern, and only dietary sources were examined.

In this regard, Sugiura *et al.* [23] who strove to examine the role of vitamins alone or in combination with carotenoids in terms of the risk of incurring osteoporosis in a follow-up study of 187 post-menopausal female subjects who participated in previous bone mineral density surveys found 15 of the post-menopausal female subjects to have developed new-onset osteoporosis. After adjustment for confounders, the odds ratios for osteoporosis in the highest tertiles of vitamins C and E and retinol intakes against the lowest tertiles were 0.15 (95% confidence interval (CI): 0.02-0.99), 0.50 (CI: 0.08-3.23), and 1.49 (CI: 0.36-6.22), respectively. Furthermore, a significantly lower odds ratio was observed in the higher vitamin C intake group (169-625mg/d) with higher serum β-cryptoxanthin (1.88-10.53μM) against the lower vitamin C intake group (47-168mg/d) with lower serum β-cryptoxanthin (0.24-1.84μM) used for the reference group ($p<0.05$). It was concluded that the combination of β-cryptoxanthin and vitamin C was inversely associated with the risk of developing osteoporosis in the post-menopausal Japanese, but the unique value of vitamin C was not assessed, and only female subjects were studied. However, Ekrol *et al.* [1] found vitamin C recipients with distal radial fractures did not benefit functionally regardless of whether the fracture was nondisplaced or displaced, nor was time to fracture healing influenced by daily 500mg vitamin C supplements applied for 50 days post fracture. This group did not report actual vitamin C intake levels or vitamin C plasma measures across groups after baseline measures were conducted, dietary records were not necessarily accurate reflections of dietary vitamin C intake or adherence to supplements in experimental group, controls may have been taking vitamin C supplements, and no subject group was found vitamin C deficient at baseline.

Other study shortcomings that limit any cogent synthesis of either prevailing stand alone studies or meta analyses include, design issues, limited samples, unknown control factors; unstudied confounding factors,

variable methods of assessing prevailing vitamin C levels or intake that rely on memory, differing degrees of bone health; the potential influences of age, gender, fracture type, site and causative mechanism, levels of daily activity, dietary intake, compliance with supplementation if relevant, and its mode of delivery, if used, plus medication usage, among other fracture healing inhibitors factors.

Table 2: *Sample of clinically oriented studies examining the association of vitamin C and fracture healing showing thematic variations and diverse approaches and categorized as either supportive or non supportive of a positive role for supplementation as per data published over the 2014-2019 time period*

Researchers	Study Approach	Finding
Support for supplementation		
Finck *et al.* [3]	Prospective study	Higher vitamin C intake correlated with higher US measures Higher plasma vitamin C related to reduced fracture risk in men
Karamati *et al.* [24]	Observational study	Diets high in vitamin C and other factors have a significant association with BMD. A nutrient pattern containing these elements, which is associated with high intakes of fruits and vegetables, may be beneficial for bone health in Iranian women
Kim *et al.* [15]	Observational study	Dietary vitamin C intake was positively associated with BMD in postmenopausal women, and inadequate vitamin C intake could increase the risk of osteoporosis
Liu *et al.* [19]	Observational study	Greater fruit intake was independently associated with better bone mineral status among Chinese elderly men and women. The association is probably modified by dietary vitamin C.
Sun *et al.* [25]	Case-control study	A higher dietary intake of vitamins C is associated with other factors in lowering the risk of hip fracture in elderly Chinese.
Torberosen *et al.* [20]	Case control study	Low vitamin C is associated with increased hip fracture risk
No support for supplementation		
Ekrol *et al.* [1]	Double-blind randomized trial	Administration of vitamin C confers no benefit to patients with a displaced or nondisplaced fracture of the distal radius

Discussion

Fractures are highly common debilitating occurrences among older individuals especially those with prevailing chronic health conditions such as osteoporosis. Their prevention as well the application of treatments to optimize fracture healing and offset any preventable further post fracture declines in bone mass are thus topics of high clinical importance. In this regard, given the documented role of vitamin C in mediating bone status, and the failure of various bone building medications to safely offset age associated bone mass declines, the question of whether suboptimal vitamin C intake levels over time have a strong bearing on the development of osteoporosis, as well as on increasing fracture risk and delayed post fracture recovery has been raised for some time. However, even though several reasonably favorable investigative reports on this

topic have been generated in both animal and human models [eg 26-28], as well as cell based studies [29,30], and that certain fruits and vegetables, which may contain varying quantities of vitamin C appear to have some clinically relevant bearing in the context of bone health [17], no report to date has provided any irrefutable support either for regarding vitamin C intake as predictive of osteoporotic fractures, or for fostering optimal fracture healing processes or for negating this possible role. In this context, while there are more favorable studies in support of vitamin C sufficiency as a bone protector than not [eg 31], very few prevailing or past reports could be deemed to meet the desired criteria for a carefully construed well-controlled randomized prospective study as outlined by Sun *et al.* [14]. Moreover, even among those that do exist, there are inconsistent clinical findings [5], for or against this idea, despite quite a sound biophysiological basis for considering vitamin C as an important mediator or moderator in the context of bone health and regeneration across the lifespan as outlined in Box 1 and Figure 1.

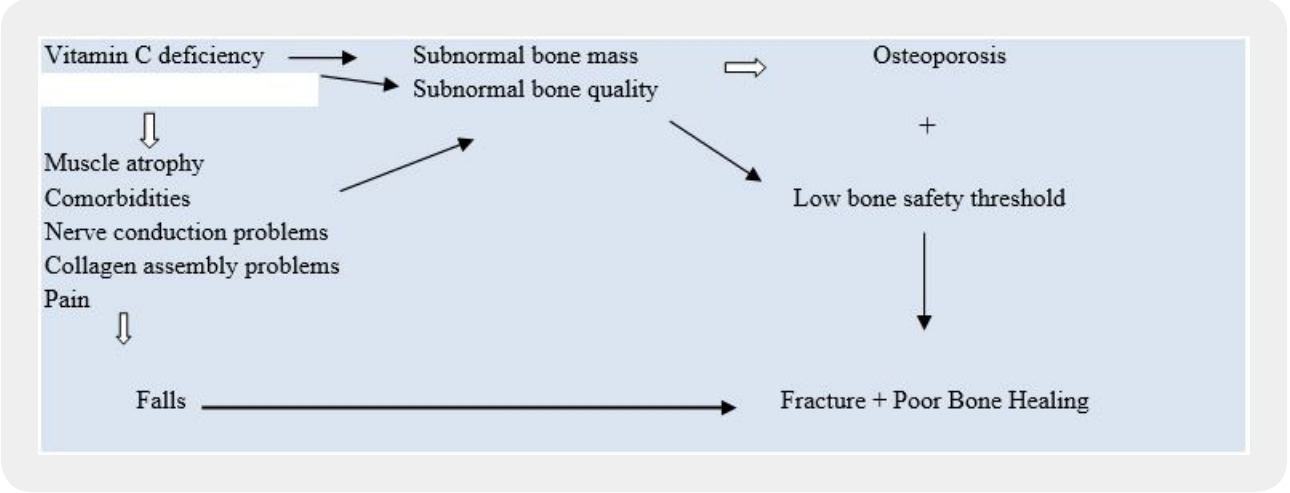

Figure 1: *Schematic Representation of the Interplay of Vitamin C Deficiency and Bone Health*

As well, limited age groups have been studied and approaches used to establish vitamin C exposure, bone mineral content and density approaches are not always comparable and findings inconsistent [5].

On the other hand, recent genetic as well as epidemiological studies, plus salient findings from recent laboratory efforts by Lai *et al.* [27], while subject to verification and replication, imply that the administration of ascorbic acid, as required, is more likely to help prevent the development of osteoporosis, than not, while increasing bone formation even in the presence of this chronic disease. Vitamin C may also help bone hygiene indirectly due to its observed promise for promoting many important biological processes, including nerve regeneration [32]; averting muscle weakness [33,34], for preventing osteoarthritis, and for improving recovery status after fractures treated conservatively or operatively [35].

Indeed, and notwithstanding the fact that studies designed to specifically examine vitamin C effects on bone health over time in human samples are limited in number as well as quality, the topic seems a promising one to pursue [3] and is one deemed to have tremendous potential [34] by several authors. In particular, not only is it generally agreed that vitamin C may play a key role in averting enormous degrees of suffering due to its

multidimensional impacts on bone as well as other body systems, but may be sufficiently potent to help in preventing or attenuating bone loss in older life and its ramifications. Vitamin C research is further showing new data concerning its beneficial effects on stem cell programming that might hold promise for improving bone healing and bone quality [32], bone degeneration and recovery [36].

To this end, rather than discarding or overlooking a potentially safe, low cost, effective adjunctive or independent bone health determinant, with a number of proven biological physiological properties, it would appear worthwhile to pursue related clinical research efforts and others that employ adequate sample sizes, stringent covariate controls, an array of bone sites, standardized vitamin C measures and dosages, and outcome variables despite challenges in doing this. More careful examination of any competing interventions and the impact of health status and age in well designed longitudinal studies and others is especially indicated [5].

Until then, since no major safety issues have been noted that align with recommendations to consume a diet that will ensure ingestion of optimal levels of daily vitamin C, and past as well as emerging studies are providing a strong case for universally ensuring aging adults have access to and are encouraged to ingest vitamin C containing foods, such as certain fruits, this idea should be considered carefully by all those seeking effective yet potentially cost-effective and highly promising strategies to advance healthy aging. At the individual level, since vitamin C has long been used to protect against many diseases including scurvy [32], health practitioners do not have to await future research in our view before applying this data, but can safely educate their clients about the importance of having an adequate daily vitamin C intake, preferably from natural sources, whilst ensuring that the client's actual plasma levels of vitamin C remain within normal limits, and foster actions to remedy any insufficiency accordingly.

While funding for fruit and vegetable studies that embody vitamin C micronutrients in measurable amounts may be unattractive to orthopedic grant funders or certain research facilities or both, when one considers the basic as well as the applied value of this line of research, more support for this at all levels of science and practice is strongly recommended for evaluating its true potential.

Indeed, at the very least, related research might not only extend our understanding of the mechanisms that foster or hinder bone health status across the lifespan, but can reveal whether vitamin C is a key factor to strongly consider in efforts to optimize bone health and healing in non-surgical and surgical situations, and in the realm of bone biology, maintenance, and regenerative processes.

Moreover, as in other areas of clinical research, since a lack of conclusive evidence may not imply ineffectiveness, but rather unanticipated research design issues, more effective research attempts to supplement available clinical results will undoubtedly prove especially beneficial in strengthening the credence of the current evidence base.

Conclusion

Although the importance of vitamin C on bone health has shown a strong association over time, and a reasonable case may be made for ensuring the desired daily intake of selected fruits and vegetables that are high in vitamin C content will be more helpful than not as far as efforts to promote bone health and healing

in aging populations [18], articles in the current realm do not all support this view [eg 1], and especially do not all test this specific view [3]. However, Hart *et al.* [35] and Lou *et al.* [37] concluded that despite the lack of definitive proof of concept, given the potential benefits of ensuring minimal vitamin C daily needs are satisfied in aging adults, and in light if its low cost, and safety profile, ascorbic acid or vitamin C supplementation in its varied forms must surely warrant consideration by orthopaedic surgeons in the treatment of a variety of musculoskeletal injuries such as fractures, as well as in their prevention [3]. Initial basic and epidemiologic studies also show a consistent array of positive bone health effects related to vitamin C, versus bone mass and quality deficiencies in the face of a vitamin C deficiency [5].

It is challenging however, to extrapolate animal based studies to the clinic. Even when attempted, the ability to differentiate specific vitamin C effects when these have been studied alongside other compounds, or other fracture determinants, and possibly alongside bone building agents or in cases where subjects with an adequate dietary intake of vitamin C in supplement based studies similarly renders the interpretation of the sought after outcomes in this line of research highly challenging at best. Moreover, whether recommended supplements or dietary vitamin C strategies are actually adhered to in clinical studies, or not, or are optimal, or whether food recall patterns are accurate measures of vitamin C or not, assuredly adds more confusion to interpreting and applying this line of research than not [eg 17]. The additional unexplored role of competing therapies, the role of health status, bone site, age, body mass, and gender that may all impact vitamin C requirements and metabolism, plus what constitutes an optimal vitamin C serum level and intake is not well standardized or articulated at all in the majority of the available studies, thus raising further questions. Additionally, as in other areas of clinical research, those highlighted in this review and others remain largely cross-sectional, thus precluding the establishment of any cause effect relationship between the variable of interest with any degree of confidence. At the same time, related meta-analyses differ in content, as well as conclusions, and some include studies that did not examine vitamin C independent effects, others eliminated some potentially telling research findings, yet others collated highly dissimilar studies. Although Hart *et al.* state the daily vitamin C recommendation to be 75mg for women and 90mg for men, there are additional research and clinical challenges because many supplements do not provide for this minimal daily recommended dosage of vitamin C, and often go unchecked. In other cases, supplements may contain up to 1500mg of vitamin C and recommended dosages exceed those in standard practice without any examination of its effect on bone over time.

Thus, despite promising basic studies in the current realm, it impossible to arrive at any definitive conclusions regarding the value of ensuring optimal vitamin C intake levels across the adult lifespan for advancing either preventive or therapeutic bone health, and what this dosage or dietary intake should be to effectively offset osteoporosis development and fracture risk for various groups. However, and to ensure that a viable cost effective prophylactic and treatment approach for many, especially the elderly who may suffer from vitamin C deficits, is not inadvertently overlooked, or treated inappropriately, it is concluded that more carefully designed clinical as well as basic research endeavors, possible policies that ensure the desired daily level of vitamin C is available to those at risk [38], along with possible periodic measures of blood concentrations of vitamin C, as well as bone quantity and quality measures in research studies, as well as in clinical practice along with related patient, practitioner, and public health education will undoubtedly prove highly valuable, and is strongly encouraged.

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