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Borates in Biomedicine: A Retrospective Analysis

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ABSTRACT

An important micronutrient exerting multiple health benefits, boron is a trace element with high potential for the treatment of neurodegenerative disease, allergic diseases, and cancer. Biochemistry and biomedical studies restarted in the early 1990s first unveiled antioxidant, anti-inflammatory, nootropic, anticancer, and antigenotoxic properties of borates including borax (sodium tetraborate decahydrate), boric acid and boron esters at low dosage, and then clearly established hormetic response of these compounds. New clinical studies conducted in the last 5 years (2020–2025) identified new potential use of borates in biomedicine and nutraceuticals, ranging from dietary supplement for bone, joint, and hormone health through new treatments for diabetic foot ulcer. The study offers a critical retrospective analysis of borates in biomedicine starting from Lister's discovery of boric acid powerful antiseptic properties in 1875. The analysis teaches an important lesson to researchers working at identifying novel therapeutic agents and to research policy managers.

1 | Introduction

Boron is an ubiquitous micronutrient whose physiological role is beneficial, if not essential, for embryogenesis, bone growth and maintenance, immune function, psychomotor skills, and cognitive functions [1]. Boron helps regulate testosterone and estrogen balance, supports bone density and calcium metabolism, reduces inflammation, improves cognitive function, and helps the body use magnesium and vitamin D properly [2].

Boron intake from food consumption is lower than 3 mg day^{-1} in most "western" diets [3], with intake for adults claimed by the World Health Organization to be safe up to 13 mg/day [4]. Average daily level of intake sufficient to meet the nutrient requirements have not yet been agreed, and borates (see below) have an hormetic behavior. However, given the health-beneficial properties of boron-containing compounds at low dosage, many countries allow the sale of boron-based dietary supplements to reach the 3 mg day^{-1} intake [5].

Recounting how boron was identified as an element with nutritional value and clinical importance, Nielsen in 2000 highlighted how "the surprising thing about this development is that only 20 years ago students in the biological and medical sciences were being taught that boron was essential for plants but not for animals" [6].

Boron compounds have long been used in medicine. In ophthalmology, boric acid and sodium borate are used to manufacture aqueous solutions employed for eye irrigation in eyelid wounds and acute chemical injuries [7], eyewash (widely and safely used by subjects with allergic conjunctivitis) [8], eyelid cleaning [9], and contact lens multipurpose solutions [10]. All these applications are due to the mild antiseptic properties (disrupting microbial cell membranes and inhibiting the growth of fungi and bacteria) and buffering capabilities of boric acid, which help cleanse the eyes, soothe irritation, and stabilize pH levels. As detailed by Wisniak in a comprehensive account on the history and chemistry of boron [11], boric (or boracic) acid (H_3BO_3) produced by treatment of borax (sodium tetraborate (NTB) decahydrate, $Na_2B_4O_7 \cdot 10H_2O$) with mineral acid, is a very weak acid with its first ionization product being 6.4×10^{-10}. Borax on the other hand "hydrolyzes in water to form a slightly alkaline

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solution that is good for cleaning, since it emulsifies grease and oil. It is not gelatinous...and crystallizes nicely" [11].

In the 1960s, Newnham discovered that ingesting about 30 mg of borax twice daily (namely more than 5 times higher dose than the aforementioned limit suggested by WHO [4]) for 3 weeks alleviated most of his arthritic symptoms, advocating the use of borax for arthritis "which the medical community did not accept" [12]. In the subsequent fifty years research established that boron intake at 3–10 mg/day rate is firmly associated with fewer cases of osteoarthritis (reducing cases by 60%) [13], with boron promoting the growth and maintenance of bone, enhancing magnesium absorption and reducing levels of inflammatory biomarkers (see below).

Biomedical studies on borates restarted in the early 1990s unveiled the antioxidant, anti-inflammatory, anticancer, nootropic, and antigenotoxic properties of both borax and boric acid [14]. Therapeutic applications of borates might include treatment of reproductive disorders, neurodegenerative disease, and cancer [2, 15]. The study offers a critical retrospective analysis of borates in biomedicine starting from Lister's discovery of boric acid powerful antiseptic properties in 1875. The analysis teaches an important lesson to researchers working at identifying novel therapeutic agents and to research policy managers. Chiefly focusing on inorganic borates, the study complements previous studies describing the use of organoboron compounds as potent therapeutics for use in anticancer, antimicrobial, antiparasitic and related other pharmaceutical uses [16].

2 | A Retrospective Analysis

In 1875, the father of antiseptic surgery, Joseph Lister, described in an article published in *The Lancet* how he developed boric acid as the active antiseptic ingredient formulated in three ways: as lotion, lint, or ointment [17]. In the article, he emphasized that in the lint used to successfully treat leg ulcers it was "a fortunate circumstance that the crystals of boracic acid, instead of being hard and harsh, like most crystals, are soft and unctuous, and therefore occasion no mechanical irritation to the skin" [17].

Writing in 1880 in the *Glascow Medical Journal* Beatson summarized Lister's achievements developing the aforementioned three boric acid-based antiseptic formulations recounting "the circumstances which brought it under his notice":

"His friend Dr. Stang of Sorweg, while on a visit to Edinburgh, informed him that a new antiseptic had been discovered in Sweden, where it was very much used for preserving articles of food and for applying to wounds. It bore the name of 'Aseptin' and was in two forms: a powder and a liquid, the latter being also known by the name of 'Amykos'. On his return home, Dr. Stang sent samples of each of the two preparations to Mr. Lister, informing him that the active principle of both the articles had been ascertained to be boracic acid.

"This substance now occupies a very important place in Lister's antiseptic method, and the reason for this antiseptic method, and the reason for this is that it possesses most marked antiseptic and deodorising properties, so that it arrests fermentative and putrefactive decomposition, and is destructive to minute organisms, such as vibrios and bacteria [18]."

Added in the early 1910s by Dakin, a research chemist, to a solution of hypochlorous acid, boric acid affords another powerful antiseptic for the treatment of infected wounds that employed to treat wounded soldiers of World War I shortly after became known as the "Carrell-Dakin solution" (today "Dakin solution" [19]. The solution usually consists of dilute NaOCl (0.4% to 0.5% in weight) and H_3BO_3 (4 wt%). Besides buffering the pH to non-irritating values between 9 and 10, boric acid exerts its antiseptic activity unveiled by Lister in the mid 1870s. Though unstable (it lasts about 1 week prior to require replacement with fresh solution) the solution was used to treat wounds of injured soldiers during Word War I, saving tens of thousands of human lives [20].

Calling boric acid an "almost entirely ineffective and at the same time dangerous even when used in ordinary ways," Watson, a medical doctor at the University of Michigan, in 1945 wrote in the *Journal of Medical Association*, that it was "time to remove that drug from general use as rapidly as possible" [21].

As shown by clinical practice and extensive work started by Lister, and advanced by Dakin and Carrell (the Nobel Laureate in Physiology in 1912), however, boric acid was highly effective, and it was never "removed from general use" in medicine. Problems administering boric acid were due to its toxicity at high doses, pointing to its pronounced biological activity and showing first evidence of its hormetic behavior (see below).

Indeed, today boric acid is widely employed since decades as active pharmaceutical ingredient in many drugs and pharmaceutical formulations. Besides use in ophthalmology [7–10], formulated either in ointment [22] or in solution typically at 3 wt% concentration, the acid is used in dermatology to treat conditions such as athlete's foot, ringworm, candidiasis, vaginitis, mild burns, diabetes wounds, and irritated skin [23]. Again, such broad scope applications are possible thanks to its antiseptic, antifungal, anti-inflammatory, and soothing properties.

3 | Recent Research Achievements

Recent clinical studies on boric acid and borates significantly further broadened the scope and this "old" family of antiseptic agents, suggesting activity also in treatment of rheumatoid arthritis. Comparing silver nitrate sponges' abilities to boric acid's broad-spectrum antimicrobial abilities and positive effects on wound healing, a clinical study conducted in Turkey in 2019 showed that the boric acid-impregnated sponge group showed a more significant reduction in wound size, epithelialization, and granulation than the silver sponge group [24]. Microscopically, fibroblasts, collagen production, and angiogenesis were all significantly higher. Thus, in combination with the negative pressure wound treatment, boric acid sponges are an excellent alternative treatment for chronic wounds.

In a randomized clinical study conducted in the USA to treat diabetic foot ulcer, a borate-based bioactive glass approved as wound

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healing agent was used in comparison to collagen alginate dressing used as standard-of-care (SOC) [25]. In detail, treatment of the wounds of patients revealed that after 12 weeks the borate glass with a target composition of $53B_2O_3$–$6Na_2O$–$12K_2O$–5MgO–20CaO–$4P_2O_5$ wt% resulted in 70% healing of wounds, compared to 25% for wounds treated with alginate, with a mean percentage area reduction of 79% compared to 37% for the latter. These were wounds that had failed multiple previous advanced therapeutics and surgeries with a mean wound age of 10 months. After a mean of 3.5 treatments, all wound healed in 6–10 weeks.

Similarly, a 2023 multicenter, randomized, controlled trial was successfully conducted in Iran applying a sodium pentaborate 3% gel or topical conventional remedy (control) to 161 patients diagnosed with diabetic foot ulcers [26]. The intervention group consisted of 71 male and 49 female patients treated twice a day for a month with an allocation ratio of 3:1 for 25 days. The control group consisted of 33 males and 8 females. 2 months after the end of the trial, most participants in the intervention group had a significantly lower diabetic foot ulcer grade (based on Wagner classification) than the control group (1.38 ± 0.73 in the intervention group and 2.29 ± 0.74 in the control group), with no case of recurrence in the intervention group versus 40% rate (and nearly 66% rate for infection) in the control group. The team concluded that the boron-based gel formulation may treat diabetic foot ulcers being and effective and affordable solution easily used in clinics.

Borate exerts its healing properties through multiple pathways, including anti-inflammatory (by inhibiting pro-inflammatory cytokines and promoting the resolution of inflammation), antimicrobial (thereby reducing the risk of infection), antioxidant (protecting cells from oxidative stress, a common feature impacting healing of chronic wounds), and pro-proliferative effects on epithelial cells (keratinocytes) whose migration and proliferation are essential for tissue regeneration and wound closure (wound healing) [27]. As healing proceeds, borate stimulates the release of growth factors involved with the deposition extracellular matrix (transforming Growth Factor β), chemotaxis (platelet-derived Growth Factor), epithelialization (fibroblast growth factor, and epidermal growth factor), and angiogenesis (vascular endothelial growth factor).

Patients with osteoarthritis [28] and with rheumatoid arthritis [29] have lower serum concentrations of boron than people without arthritis, suggesting that supplementation with boron compounds may be useful in the prevention and treatment of arthritis.

A double-blind randomized clinical trial conducted in Iraq in 2017 showed that both calcium fructoborate (CFB) and NTB, when used alongside standard rheumatoid arthritis treatment (etanercept), significantly improved clinical scores and reduced inflammatory markers, with remarkable superiority for CFB over NTB [30]. In detail, the clinical trial involved a 60-day treatment of 76 rheumatoid arthritis patients randomized into three groups to receive either 220 mg/day CFB, 55 mg/day NTB in capsule dosage form (equivalent to 6 mg elemental boron), or placebo formula once daily. After 60 days, both boron compounds significantly improved the clinical scores, in association with significant decrease in the serum levels of ESR (DAS28-erythrocyte sedimentation rate), high-sensitivity C-reactive protein (hsCRP), IL-1α (interleukin-1α), IL-6 (interleukin-6), and TNF-α (tumor necrosis factor-α).

4 | Safety and Hormetic Behavior

As mentioned in the introductory text, problems administering boric acid were due to its toxicity at high doses, pointing to its pronounced biological activity and showing first evidence of its hormetic behavior. Recounting a case of acute toxicity involving a 44-year-old woman who attempted suicide ingesting "half a container of boric acid powder" [31], in 1982 Shalita and coworkers described the severe dermatological manifestations, including generalized erythroderma and extensive desquamation [31]. The paper, which opened noting how "numerous studies indicated that the drug has relatively little therapeutic value, and its accidental use has resulted in significant morbidity and mortality" [31] concluded Noting how the Food and Drug Administration Over the Counter Advisory Panel had "recommended that the availability and use of boric acid be restricted" suggesting that boric acid ointment "should carry a warning label that it is not to be used on inflamed skin, open wounds, and especially on large wounds such as burns," the team called boric acid "a potentially dangerous yet poorly effective substance" [31].

As surprising as it may seem, in 2026 lethal and tolerable doses of boric acid have not been established [32]. Matsuoka and coworkers in Japan recently reported that the estimated lethal dose for adults ranges from 15 to 20 g [33, 34], with retrospective analysis of 784 acute boric acid ingestions indicating that doses ≥3 g were tolerated in children under 6 years and doses exceeding an estimated 8 g were tolerated in adults [34]. Yet, in the same study they reported how a 56-year-old man who had ingested 91 g of boric acid, following a gastric lavage and two rounds of hemodialysis was discharged without sequelae after just 6 days of hospitalization [35].

In brief, to date a definitive consensus on the actual toxic levels of boron has not been reached. In general, newborns and infants are significantly more susceptible to boron high bioactivity. For example, in 1987 lethal poisoning doses for boric acid were 1–3 g in newborns, 5 g in infants, and 20 g in adults [36]. Recounting the case of a 8-year-old boy who consumed food prepared with water inadvertently contaminated with a 3% boric acid solution (estimated intake: 2.7–8.1 g), lately physicians in Italy recommended that ingestion of boric acid ad doses exceeding 3 g warrants immediate hyperhydration and monitoring [37].

In 2023, summarizing results on boron compounds bioactivity, a joint team led by Calabrese highlighted the term hormesis in the boron biochemistry literature was rarely present, even though hormetic dose responses were ubiquitous [38]. Hormesis, we briefly remind, indicates a biphasic dose–response with a low dose inducing stimulation and beneficial effect and a high dose producing inhibitory or toxic effect. We know today that hormetic response typically involves enzymes such as kinases and deacetylases, and transcription factors such as nuclear transcription factors Nrf2 (erythroid 2p45 (NF-E2)-related factor 2) that regulates the cellular antioxidant response and NF-κB (nuclear factor kappa-light-chain-enhancer of activated B cells) activated

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by stressors (cytokines, UV, radicals) to trigger expression of genes involved in immunity, inflammation, cell proliferation, and survival [39].

Indeed, building on work showing the effect of boric acid on thymic cytokine expression, hormone secretion, antioxidant functions, cell proliferation, and apoptosis potential via the extracellular signal-regulated kinases 1 and 2 signaling pathway [40] and that boron activates the mitogen activated protein kinase (MAPK) pathway which led to enhanced cell proliferation and growth at low concentrations with inhibition of this activation at higher concentrations [41], Calabrese and coworkers highlighted in their review the underlying mechanism for hormetic effects driven by borate [38]. The mechanism involves activation of the MAPK pathway stimulating cell growth, differentiation, and proliferation via ERK1/2 and c-Jun N-terminal kinase (JNK) signaling pathways with optimal treatment concentration of 80 mg/L, while at high concentrations borate becomes inhibitory (and subsequently toxic).

The team highlighted how the hormetic behavior of boron compounds (and chiefly of borates) is clinically more important than essentiality, suggesting that the effects of boron compounds on human health and disease should be re-explored in light of this hormetic mechanism. In other words, the fact that boron affects a substantial number of organ systems in a hormetic manner with a very similar optimal dose range has important medical implications. For example, with respect to bone growth, boron supplementation enhances stem cell differentiation via the activation of osteogenic genes [42].

5 | New Nutraceutical Uses

In 2021, the European Food Safety Agency (EFSA) approved the use of CFB as novel food (dietary supplement) aimed at the adult population (excluding pregnant and lactation women) with a maximum daily dosage of 220 mg (based on a maximum boron intake of 6.4 mg per day) [43]. Commercialized with the tradename “FruiteX-B,” CFB provides bioavailable boron for bone, joint, and hormone health, supporting mobility, bone strength, and nutrient utilization [44]. Boron plays a crucial yet often overlooked role in bone metabolism through its interactions with vitamin D and estrogen metabolism [45]. Human studies indicate that boron deprivation leads to increased urinary excretion of calcium and magnesium, while supplementation can reduce these losses by 30%–40% [46].

In 2023, re-examination of data for CFB pilot study [47] showing reduced overall joint discomfort reported in 90-day, double-blind, randomized, placebo-controlled clinical trial to evaluate the effect of CFB on knee joint discomfort of 62 female and 59 male subjects, found that by day 30, both CFB groups were distinguishable from placebo with individual differences in at little as 14 days [48].

In 2018, following previous study showing that a twice-daily 108 mg dose of CFB improved knee discomfort during a 2-week supplementation period [46], a new double-blind, placebo-controlled randomized study investigated the effects of CFB supplementation with a daily 216 mg dose on knee discomfort during 90 days of supplementation to two groups of 40 participants with self-reported knee discomfort each receiving the dose and 40 receiving a placebo [49]. Again, results showed that CFB supplementation resulted in early and significantly improved levels of knee comfort. Knee comfort continued to significantly improve throughout the duration of this 90-day study. No significant differences were observed between the once-daily and the twice–daily doses of CFB.

These data provide further evidence of the substantial health benefits of fructoborate for joints and in improving daily physical activity. Supplementation of borate would resolve the deficiency of B inhibiting the synthesis of the active form of vitamin D (calcitriol, 1,25-$(OH)_2$-D_3) and assimilation of Ca, leading to osteoporosis and arthritis.

Commercialization of borate-based dietary supplements for treatment and prevention of osteoporosis, in bone remineralization, and in the repairing of connective tissue, already flourished in Australia already in the early 2010s, when a study on the nutraceutical use of boron compounds found 14 oral boron-containing supplements already licensed (generally with doses less than or equal to 3 mg boron/day, primarily in combination with calcium, magnesium and vitamin D) [50]. Today, driven by increasing consumer awareness of bone and joint health as well as its efficacy in treating arthritis, CBF has replaced borax or boric acid and active nutraceutical ingredient becoming a widely consumed dietary supplement. Its global market, valued at nearly \$100 million in 2024, was lately forecasted to expand at nearly 8% annual growth rate till 2033 when it is projected to reach nearly \$200 million [51]. Boron glycinate is another bioavailable boron ester used for boron supplementation for example to enhance cognitive performance, to support joint health, enhance bone strength and aid in the metabolism of essential minerals like calcium, magnesium, and vitamins such as vitamin D.

Indeed, it is known since the mid 1990s that a low boron intake shifts the electroencephalogram towards patterns consistent with poor mental alertness, whereas boron supplementation enhances attention, long- and short-term memory, manual dexterity, and eye–hand coordination [52]. Ending the study reporting the latter clinical trial, Penland concluded that these findings provided “additional evidence that boron is an essential nutrient for humans” [52]. Indeed, noting that boron is present in healthy tissues of different animals at comparable concentrations and that tissue concentrations during short-term variations in intake are maintained by homeostatic mechanisms, that boron is toxic only at relatively high doses, and when depleted prevents growth and results in reduction of a physiologically important function, in 2007 Hunt concluded that boron is an essential element both for man and for animals [53], and not only for plants.

More recently, following the discovery that boric acid and other boron-containing compounds are neuroprotective agents able to modulate inflammation and oxidative processes as well as amyloid-β aggregation inhibitors, they are investigated as novel drugs for the treatment of Alzheimer’s disease [54, 55].

The rediscovery of borates as broad-scope therapeutic agents is exemplified by the recent discovery that of cytotoxic and proapoptotic effects (inducing programmed cell death in gastric

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adenocarcinoma cells) of boric acid on human gastric adenocarcinoma cells in vitro [56], as well as cell triggering autophagy in cervical cancer HUF and HeLa cell lines [57].

6 | An Essential Nutrient?

In 2007, Hunt showed that boron meets all criteria for essentiality [53]. Yet, according to the National Institutes of Health (Office of Dietary Supplements), "boron is not classified as an essential nutrient for humans because research has not yet identified a clear biological function" [58]. In other words, boron remains classified as a possible essential nutrient.

Trying to answer to reason of this conflict and noting that daily requirement of B is so low (at least 1.0 mg day^{-1}), that in experiments of nutrition on humans it would be necessary to control all sources to supply this element on human diet, Sosa-Baldivia and coworkers in 2016 aptly suggested to analyze boron in hair in areas where high incidence of osteoporosis and arthritis are common amid the population [59]. Hair analysis of trace metal elements is better than urine and blood analysis because it reflects the long-term nutritional status [60]. Indeed, in 2018 Russian and Croatian researchers reported that the boron nutritional status in men and women can be assessed by analyzing its cumulative frequency distribution in the hair, significantly better than in whole blood where concentration will be 40–100 times lower [61]. Finding hair concentration values of 0.771–6.510 µg/g for men and of 0.472–3.89 µg/g for women, the team suggested to use the adjective "semi-essential" for elements like boron that "do not qualify them as essential by Koch's criteria but which do have some proved beneficial functional properties" [61].

To date, Sosa-Baldivia's and coworkers' suggestion has not been followed by researchers. However, amid the 8 research papers that (up to early 2026) cited the latter seminal hypothesis paper [59], there was the first clinical study in which dietary boron intake was increased by adding intake of boron-rich foods [62] with the aim to identify the effect of increased dietary boron intake on important biochemical and hematologic parameters in humans.

In detail, thirteen healthy women were asked to consume diets containing 10 mg more boron than their routine diet for 1 month, providing the extra boron intake by increasing the intake of boron-rich foods such as dried fruits, avocado, and nuts in the diet. After 1 month serum, salivary, and urine boron concentrations, respectively, increased 1.3, 1.7, and 6-fold, whereas triglyceride levels decreased significantly alongside 1.1% (800 g) reduction in body weight (with almost all reduction being in body fat weight) achieved without reducing calories [62]. Furthermore, the salivary boron level increased from 0.06 ppm to 0.10 ppm, translating into an increase in saliva buffering capacity from 4.42 to 5.21 at the end of the 1-month boron-rich diet, which may have a cariostatic effect (subjects with high buffering capacity are more resistant to caries).

7 | Conclusions

In summary, a retrospective analysis of biomedical utilization of borates (boric acid, borax, and subsequently boron esters) shows how the use of boric acid as the active antiseptic ingredient formulated as lotion, as lint, as ointment was introduced in 1875 by the father of antiseptic surgery, Joseph Lister to treat leg ulcers. Formulated alongside hypochlorous acid (the Carrel-Dakin solution) boric acid from 1915 will save the life of thousands of injured soldiers in World War I. Yet, in 1945 writing in the same medical journal in which Lister had reported his discovery in 1875, based on a number of fatalities occurred with use of high doses of boric acid, Watson called for its "removal from sale as rapidly as possible."

New biomedical research on boron restarted in Australia in the 1960s when Newnham unveiled potential use of borate in treatment of arthritis and, subsequently, of osteoporosis. This slowly led to new biochemistry research aimed at identifying the mechanism by which borates would promote bone growth and ease joint pain in subjects suffering from arthritis.

The early 2000s saw first commercialization of borate-based dietary supplements for treatment and prevention of osteoporosis, in bone remineralization, and in the repairing of connective tissue, in many countries including Australia, the USA, and several European countries. In the early 2020s, also thanks to the lack of toxicity at low dosage and low cost of borates, a number of clinical studies were conducted to evaluate their efficacy including in clinical trials more bioavailable forms of borates such as CFB. Conducted both in industrially developed countries such as USA and Australia and in economically developing nations (such as Iraq, Turkey, and Iran), these studies were generally successful establishing new treatments for serious pathologies such as diabetic food ulcer.

Research continued and the positive effects of boron supplementation on cognitive function were identified, while biochemistry research eventually identified a common trait to boron bioactivity: hormetic response, in which low-dose/concentrations induce stimulation, and high-dose/concentrations produce inhibition giving place to a U-shaped dose–effect relationship.

Finally, recent research identified in vitro anticancer activity of boric acid at low dose driving apoptosis of different human cancer cells including gastric adenocarcinoma and cervical cancer cells, as well as neuroprotective action.

In brief, the analysis of biomedical utilization of borates provides a learning example at the cross-road between chemistry and medicine of Lévy-Leblond's historical hysteresis in the development of science [63] for which many scientific developments often remain shelved and forgotten until rediscovery occurs. The relevance of the discoveries of Lister first and Dakin and Carrel on the antiseptic properties of boric acid later, had become evident to surgeons in Europe during World War I. In 2019, surgeons will call Dakin's solution "one of the most important and far-reaching contributions to the armamentarium of the surgeons" [64], regardless of the 1945 call for removal from sale.

Similarly, research in the biomedical (and then also in the nutraceutical) properties of borates continued regardless of the lack of recognition of boron as an essential nutrient, and of the fact that the medical community for years was skeptical about the activity of borates in treatment of arthritis and osteoporosis.

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An important lesson for both biochemistry and biomedical researchers and research funders, therefore, is to continue to conduct (and to fund) research potentially of high medical relevance even when the science around a topic is controversial and perceived with skepticism by many researchers.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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