Effect of keraGEN IV Keratin oral supplementation on hair, skin, and nail attributes

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Abstract

Background: Skin attributes reflecting problems in the underlying structure can include a lack of elasticity and hydration, while problems with hair health may be indicated by hair loss. Hair anchoring is important in mitigating hair loss typical of that experienced during combing or styling, when hair is damaged through chemical treatments, coloring, or during peri- or post- menopause. Nail health, including nail keratin content, can be negatively affected by a variety of agents including nail cosmetics and chemicals. The unique properties of the structural protein keratin provides strength, resilience, and protection to skin, hair, and nails. In this article, we discuss the role of keratin in various dermatological conditions and evaluate the effect of ingestion of a novel keratin-based formulation on hair skin and nail health.

Materials and Methods: A randomized, double-blind, placebo-controlled non-invasive study was conducted in 65 female subjects aged 45-60 having healthy skin, but damaged or stressed hair. Instrumental measures of skin firmness and elasticity, hydration, and skin barrier function efficiency were taken along with a hair pull test, keratin quality assessments and participants' self-assessment of nail condition over the 60 days of the study.

Results: The investigational product's action of inducing collagen IV expression appears to translate to measurable improvement in hair anchoring, specifically a 43.1% reduction ($p \leq 0.01$) in hair loss in women aged 45-60 with stressed or damaged hair. Improvement in the hair keratin structure is further supported by a 17.61% increase ($p \leq 0.01$) in birefringence arising from increase in the hair cortex structural integrity following evaluation using polarimetric imaging analysis. The measured 12.5% reduction ($p \leq 0.05$) in trans epidermal water loss (TEWL) may arise from the improvement of skin structure and associated barrier function due to collagen IV expression induced by the investigational product - keraGEN IV®. Improvement in skin health and skin structure due to the investigational product is reinforced by the measured improvement in skin elasticity, increasing by 10.1% ($p \leq 0.001$). Evidence does not support a difference in either nail strength or overall condition based on whether the investigational product or the placebo was taken.

Conclusion: The use of oral keratin supplementation containing the investigational product keraGEN IV® resulted in improved skin structure, hair structure and reduction in hair loss from pull testing associated with the health of the underlying structures.

Keywords: keratin, nutraceuticals, supplements, health claims

1. Introduction

Skin, hair, and nails are external markers of health and well-being. These structures are partially composed of keratin, a family of fibrous proteins essential to the structural framework of the epidermis and its appendages. Keratin is a tough, insoluble protein that provides strength and resilience to these structures, protecting them from environmental stressors such as heat, cold, oxidative stress and mechanical trauma. In this article, we examine the importance of keratin in maintaining the health and integrity of skin, hair, and nails and investigate the effect of a novel keratin-based formulation on these structures.

Keratin production is influenced by various factors such as genetics and hormonal and nutri-

tional status, including sulfur amino acid metabolism. It's crucial to understand how to support the production and function of keratin since it plays both physical and biological roles in the body, affecting wound healing rates, stimulating protein synthesis, and building healthy skin structures[1, 2]. Therapies based on keratin have shown promise in treating dermatological conditions like epidermolysis bullosa[3], which causes the skin to become very fragile and leads to blistering lesions. Keratin also forms a protective barrier that prevents water loss and protects against environmental pollutants and pathogens. When added to an ointment base, keratin hydrolysates have been found to have humectant (increasing hydration in the stratum corneum) properties as well as occlusive (decreasing trans-epidermal water loss[4]) properties. With this promising baseline for both healing and protection, further research on the effect of keratin on skin characteristics is warranted.

Oxidized keratin promotes keratinocyte migration, which induces protein expression of collagen types IV and VII[5]. Unlike collagens I, II and III that are highly abundant in soft tissue and contribute to overall tissue strength and integrity, collagen IV is a junctional protein that is crucial in joining the epidermal and dermal layers of the skin and anchoring hair in the hair follicle. Low levels of collagen IV have been found to correlate with hair loss[6]. In some cases of alopecia areata, the breakdown of immune tolerance leads to destruction of the hair follicle and loss of keratinocytes resulting in hair loss[7]. Studies have shown that oral[8, 9, 10] and topical[11] keratin supplements can produce a positive effect on keratin biosynthesis and content, improving hair growth and quality.

Nail strength, hardness, flexibility, brittleness, and toughness are all characteristics of overall nail health. Nail cosmetics, chemicals, physical injury, generalized disease, and genetic disorders can negatively affect nail health and the keratin content of nails[12, 13]. Keratin-based formulations can improve the appearance and texture of nails, such as when affected by the common fungal infection onychomycosis[14, 15, 16].

Nutrients such as biotin, zinc, and sulfur are small molecules readily absorbed by the body and essential for the production of keratin. Keratin is made up of long, coiled polypeptide chains that form intermediate filaments uniquely rich in the sulfur amino acid cystine. The unique structure of keratin provides strength and elasticity to the skin, hair, and nails, allowing them to withstand repeated exposure to mechanical stressors such as bending, stretching, and twisting. Keratin protein has been established as a safe and effective source of cysteine with the ability to influence sulfur metabolism including glutathione and taurine levels when presented in a digestible form[17]. Once ingested, keratin in a digestible form is available to be broken down by digestive enzymes leading to absorption of bioavailable keratin peptides that are then have the potential to influence cell metabolism. Exploring the potential effects of keratin-based formulations on relatively healthy adults may lead to the development of new and effective treatments for health conditions in the long-term. In the short-term, it may help manufacturers develop products that maintain the health and integrity of these structures, which can be beneficial for consumers.

The use of dietary supplements for potential health benefits has increased in recent years, mainly due to the growing interest in health and wellness among consumers[18, 19]. When there is evidence to support their use in preventing, improving, and/or treating diseases or health conditions, dietary supplements are more accurately referred to as nutraceuticals[20]. These nutraceuticals are available in various forms, including tablets, capsules, gummies, and powders. In some cases, ingestible forms of these compounds may be more effective in delivering potential benefits than topical administrations[21]. Popular supplements for skin, hair, and nail health include multivitamins, biotin/B7, ascorbic acid/vitamin C, zinc, and collagen[22]. This study aims to investigate to what extent keratin also supports these structures.

The objective of the current study is to examine a novel proprietary keratin-based supplement's effect on user well-being, including:

- skin structure,
- hair follicle anchoring and hair condition,
- nail quality, and
- satisfaction and tolerance of the supplement.

2. Materials and Methods

The research was structured as a randomized, double-blind, placebo-controlled non-invasive study conducted at single site in France (Laboratoire BIO-EC) over 60 days in 65 subjects, aged 45-60. The interventional group comprised n=32 while 33 participants were in the placebo group; one volunteer assigned to the placebo group was excluded from the D30 analysis after not attending the D30 visit. Figure 1 presents the research stages.

In the period leading up to and including D0, study details were explained, participants were informed of possible adverse effects from using the product, and a correct understanding of the study was ascertained. Each participant then signed an informed consent document, including consenting to undergo a general clinical examination attesting to their ability to participate in the study.

Potential participants were evaluated by a dermatologist against inclusion and exclusion criteria set by the study. Inclusion criteria included that volunteers were healthy Caucasian women aged from 45 to 60 years old having healthy skin, but damaged or stressed hair. In accordance with recommendations of French law on biomedical research, participants needed to be affiliated to the French social security system and needed to understand the French language to be able to read the documents presented and freely adhere to what was explained.

In addition to not fitting the inclusion criteria or participating or intending to participate in another study, non-inclusion criteria included pregnancy, breastfeeding, or wishing to be pregnant during the study time frame; having surgery planned during the study; suffering from systemic diseases, pathologies, or any dermatosis likely to interfere with the study; having an allergy or hypersensitivity to food products or any component of the study product; or showing signs of recent intense sun or UV exposure or having recently carried out aesthetic treatments (e.g. scrub, peeling, self-tanning, depigmenting, etc.) that could confound study results. In addition, potential participants who could not be contacted urgently by phone, were unable to follow study protocol requirements, or were deprived of liberty or were otherwise protected by law were excluded from this study. Vegetarian and vegans were also excluded as the nature of the investigational product conflicts with these dietary choices.

Each participant meeting the inclusion criteria was weighed and given a clinical exam including recording general and dermatological features, hormonal status, and contraceptive method. A baseline assessment of hair was conducted.

At D2, biometrological measurements were taken, including measurements of skin firmness and elasticity, skin hydration measures, and skin barrier function efficacy measurements.

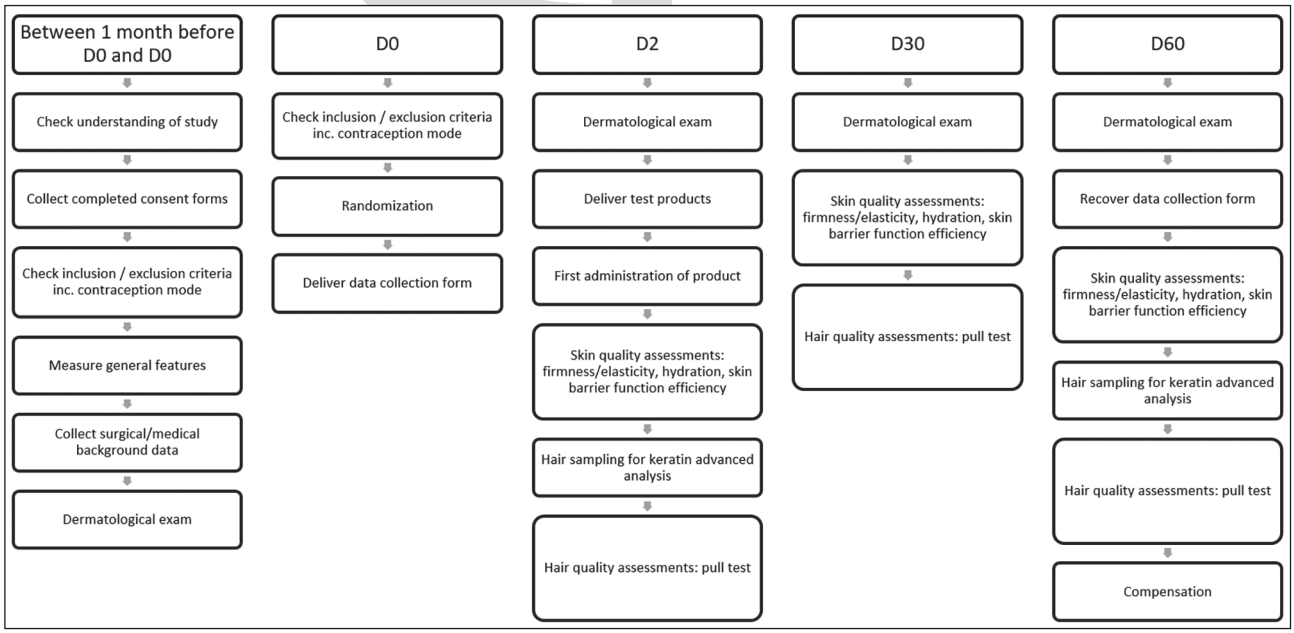

Figure 1. Clinical Design Flow Chart

The test product was given to the volunteer. The investigational keratin product (keraGEN IV®) tested is a highly bioavailable form of keratin supplied by Keraplast Manufacturing (Christchurch, NZ; patent application number US 20120219667A1). The investigational product consisted of 200 mg of keraGEN IV® and 550mg of microcrystalline cellulose; the placebo (also supplied by Keraplast Manufacturing) consisted of 750mg of microcrystalline cellulose. The product was in powder form contained in a transparent capsule packed in a white opaque bottle, to be kept at room temperature. Participants were asked to take two capsules once a day, every morning, swallowed with a glass of water, over the 60 day study period.

At D30, volunteers were weighed, and dermatological control (hair pull test, evaluation of hair and nail qualities) were performed to assess tolerance of the investigational product. Biometrological measurements were taken. During the final D60 visit, volunteers were weighed, biometrological measurements were taken, and the test product was returned, as well as a self-assessment questionnaire investigating the user's experience. Compensation was given to the volunteer.

Clinical assessment of hair and skin was done in seven different ways.

2.1 Hair pull test

The hair pull test helps evaluate diffuse scalp hair loss and follicle anchoring in the scalp. Gentle traction is exerted on small group of hairs (about 60) in three areas of the scalp (frontal, temporal, and occipital) and the number of extracted hairs is counted. The dermatologist takes a few strands between his/her thumb and forefinger and pulls them gently. In the anagen phase, growing hair should remain rooted in place while hair in the telogen phase will come out easily. If the number of lost hairs is greater than nine, the pull test is suggestive of telogen effluvium (temporary hair loss). Volunteers are asked to refrain from washing their hair for two to three days before the pull test.

2.2 Hair sampling for keratin analysis

Hair cross sections of 30µm thickness, cut at a 35◦ angle of two volunteers were sampled, one for the investigational product and one for the placebo. Thirty hair segments of 1 cm length per volunteer were analyzed both before and 60 days after supplementation. Polarimetric imaging analysis (performed by KAMAX company, France) allowed the effect of the investigational product and placebo on the keratin structure of the cortex of the hair at the molecular level to be evaluated by quantifying the birefringence of the sample. Greater keratin organization in the hair cortex results in greater birefringence and is indicative of high hair fibre structural integrity. The K_{index} value of the sample is a measure of how light is polarized as it is transferred through a hair segment, the birefringence. This is a quantification of keratin integrity in the hair cortex. The darkest hair shade accepted for analysis was dark brown as melanin interferes with the analysis.

2.3 Dermatological exam of hair quality

The hair appearance was evaluated by a licensed dermatologist who assigned a score of one to three based upon the person's hair brightness and luster. A score of 1 is dull and devoid of brightness, a score of 2 is basically dull and not so bright, and a score of 3 is shiny and bright.

2.4 Skin firmness/elasticity

Courage & Khazaka Electronic's MPA580 Cutometer® with a 2 mm diameter probe was used to evaluate the deformation of a skin area and its recovery skill after being subjected to mechanical suction stress. During the suction phase, the deformation of the skin by negative pressure measures first the elastic resistance, then the viscous component which, together, represent skin firmness. The immediate recovery of the skin measures sheer cutaneous elasticity, whereas the delayed return of the skin to its initial position measures the visco-elastic component. Skin firmness/elasticity measures were taken at the beginning of the study, and at 30 and 60 days.

2.5 Skin hydration

A probe linked to a condenser is the basic technology used by the Corneometer CM825TM by Courage & Khazaka Electronic. This technology was used at the study's beginning, and at 30 and

60 days to measure skin hydration by noting variation in electric capacity. Higher hydration is indicated by higher electric capacity values. Forearm skin was tested.

2.6 Skin barrier function efficacy

The Trans Epidermal Water Loss (TEWL) assessment evaluates the skin barrier function efficacy and is indicative of the skin structure and integrity of the stratum corneum. The TEWL value is inversely proportional to the barrier function. TEWL measures of the quantity of evaporated water (TEWL g/hm2) were taken with Courage & Khazaka Electronic's Tewamètre ® TM300 based on an open room diffusion technique. At the beginning of the study and at 30 and 60 days about twenty successive measures (one measure per second) were taken on the same area and the mean value was recorded. Forearm skin was tested.

2.7 Dermatological Controls

A dermatological control was performed at the beginning of the study (D0), on day 30 (D30) and at the end of the study (D60) to assess users' tolerance of the products.

2.8 Statistical Analyses

Intra-product and inter-product comparisons over time were made using Student's t-test and the Wilcoxon signed rank test.

3. Results

3.1 Hair Assessments

3.1.1 Hair Pull Test

While neither the investigational product nor the placebo had a significant effect on hair loss after 30 days of use, volunteers taking the keraGEN IV® supplement demonstrated a substantial and statistically significant reduction in hair pull scores on day 60. Reduction compared to day 0 was -43.1% ($p \leq 0.01$). By day 60 the placebo recorded a modest but not statistically significant reduction in hair pull scores of -14.1% compared to day 0 ($p \geq 0.1$). Figure 2a shows intra- and inter-group percentage change in hair loss as a result of the hair pull test for keraGEN IV® and the placebo at day 30 and day 60 compared to day 0 and compared to each other at both days 30 and 60.

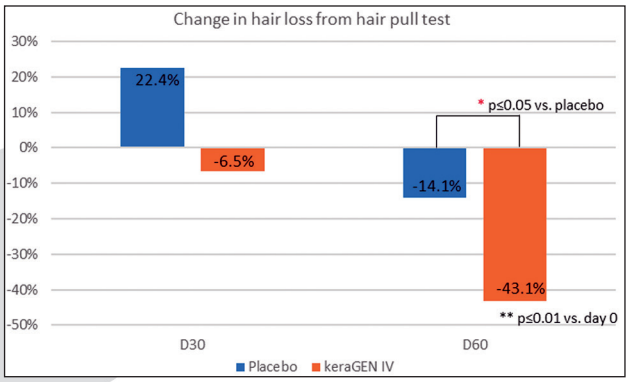

Figure 2a. Hair loss percentage change between keraGEN IV® and placebo at day 30 and day 60 compared to day 0

Compared to both baseline and the placebo, keraGEN IV® significantly decreased the hair pull test score thus significantly decreasing hair loss after 60 days of use.

3.1.2 Hair sampling for keratin analysis

The analysis of keratin fibers shown in figure 2b revealed an increase from 86.08($x10^{-4}$) to 101.24 ($x10^{-4}$), a 17.61% improvement in the treatment group volunteer's hair cortex after 60 days of supplementation, with statistical significance ($p \leq 0.01$). The Kindex mean value of the control group volunteer increased from 67.1($x10^{-4}$) to 71.76 ($x10^{-4}$), a variation of 6.94%, although this was not a statistically significant change. This suggests that KeraGEN IV® significantly increased the structural integrity of the hair cortex after 60 days of use.

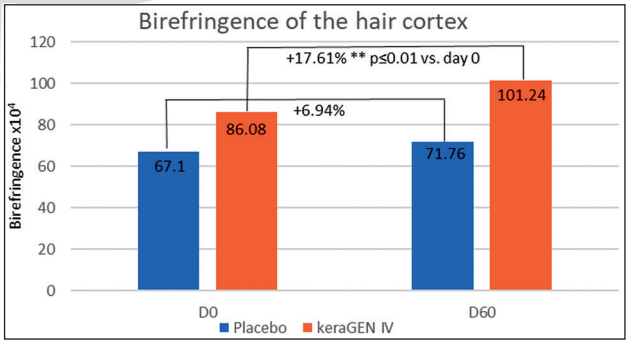

Figure 2b. Birefringence of hair cortex after 60 days of keraGEN IV® or placebo treatment

3.1.3 Dermatological exam of hair quality

Neither keraGEN IV® (p≥0.1) nor the placebo (p≥0.1) affected any significant change in hair luminosity and luster over the study time or compared to each other. Results from measurements done for hair are summarized in Table 1.

3.2 Skin Assessments

3.2.1. Skin firmness/elasticity

Neither the investigational product nor the control had an effect (p≥0.1) on skin firmness over the course of the study. As shown in figure 3a, neither supplement had an effect on gross elasticity (R7) at day 30 and the placebo still did not produce an effect at day 60. KeraGEN IV®, however, increased gross elasticity of the skin by 10.1% over the baseline (p≤0.001) by day 60; the effect was also significant compared to the placebo (p≤0.05).

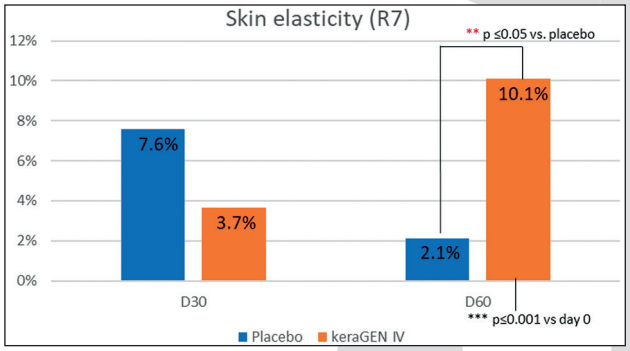

Figure 3a. Percentage change skin elasticity (R7) for keraGEN IV® and placebo at day 30 and day 60 compared to day 0. Statistical significance given vs. day 0 and vs. placebo at the same time point

3.2.2. Skin hydration

Neither the investigational product nor the control had a significant effect on skin hydration during the study compared to baseline or when compared to one another (p≥0.1).

3.2.3. Skin barrier function efficacy

TEWL measurements on day 30 volunteers taking the keraGEN IV® supplement were lower at -12.5% compared to day 0 with statistical significance (p≤0.05) (figure 3b).

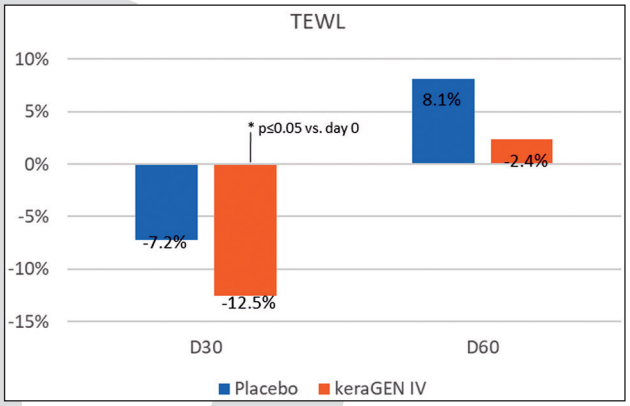

Figure 3b. Percentage change in trans epidermal water loss (TEWL) for keraGEN IV® and placebo at day 30 and day 60 compared to day 0. Statistical significance given vs. day 0 and vs. placebo at the same time point

Measurements on day 60 were not significantly different from day 0 (+2.4% increase, p≥0.1). Volunteers in the placebo group at day 30 also measured lower TEWL at -7.2% however this and

Table 1. Hair Results Summary

Assessment	Mean ± Standard deviation (1/cm²)			P values (+ Wilcoxon test, ++ Student's t test)	
	D0	D30	D60	D30	D60
Hair Pull Test					
keraGEN IV®	4.8 ± 4.2	4.5 ± 5.9	2.7 ± 3.0	0.3703 + Vs. placebo 0.1804++	0.0031 + ** Vs. placebo 0.0536++*
Placebo	2.9 ± 3.3	3.5 ± 5.8	2.4 ± 2.7	0.7186 +	0.9825 +
Hair sampling for keratin analysis					
keraGEN IV®	86.08 $^{10-4}$	N/A	101.24	N/A	0.0041 + **
Placebo	67.1$^{10-4}$	N/A	71.76$^{10-4}$	N/A	0.0707+
Hair quality (luminosity and luster)					
keraGEN IV®	1.8 ± 0.4	2.2 ± 0.5	2.3 ± 0.5	0.9615+ Vs. placebo 0.2571++	0.8340+ Vs. placebo 0.2900++
Placebo	1.9 ± 0.3	2.1 ± 0.4	2.2 ± 0.5	0.9993+	0.9414+

** Significant p≤0.05 **Significant p≤0.01 ***Significant p≤0.001*

the day 60 result (increase of +8.1%) was not statistically significantly different to day 0 ($p \geq 0.1$). Compared to placebo, the changes in skin barrier function at day 30 or day 60 did not achieve statistical significance.

Results from measurements of skin quality are summarized in Table 2.

3.3. User Experience / Questionnaire results

3.3.1. Dermatological control results

There was a very good tolerance of both keraGEN IV® and the placebo after 30 and 60 days of use. No adverse effects occurred during the study.

3.3.2. Skin self-assessment

An inclusion criterion for the study was that participants had "good" skin as evaluated by a dermatologist. The majority of participants echoed this evaluation by rating their skin appearance as either "good" (keraGEN IV® 15.6%, placebo 15.1%) or "average" (keraGEN IV® 81.3%, placebo 75.8%) with few rating their skin as "poor" (keraGEN IV® 3.1%, placebo 9.1%).

By the end of the study, the majority of those taking the investigational product felt that their skin had either significantly improved (3.1%) or improved (43.8%) with few feeling that their skin had gotten worse (3.1%). In the placebo group,

Table 2. Effect of the Investigational Product on Skin Quality

Assessment	Mean ± Standard deviation (1/cm²)			P values (+ Wilcoxon test, ++ Student's t test)	
	D0	D30	D60	D30	D60
Skin firmness (R0)/elasticity (R6)/ skin gross elasticity (R7)					
keraGEN IV® (n=32)	0.293 ± 0.034 (R0)	0.295 ± 0.037	0.293 ± 0.034	0.7534++ Vs. Placebo 0.3238++	0.9882++ Vs. Placebo 0.4159++
	41.39 ± 6.62 (R6)	40.60 ± 4.34	42.11 ± 5.97	0.5146++ Vs. Placebo 0.4906++	0.5867++ Vs. Placebo 0.4989++
	24.67 ± 4.93 (R7)	25.57 ± 6.47	27.16 ± 3.57	0.3616++ Vs. Placebo 0.4823++	0.0011++ ** Vs. Placebo 0.0189++*
Placebo (D30 n=32, D60 n=33)	0.305 ± 0.040 (R0, D30) 0.305 ± 0.039 (R0, D60)	0.301 ± 0.044	0.304 ± 0.041	0.4322+	0.8481++
	41.61 ± 5.32 (R6, D30) 41.51 ± 5.26 (R6, D30)	40.68 ± 7.17	42.77 ± 5.77	0.3865++	0.1952++
	26.71 ± 6.29 (R7, D30) 26.44 ± 6.38 (R7, D60)	27.42 ± 6.74	26.78 ± 6.40	0.3744+	0.2347
Skin hydration					
keraGEN IV® (n=30)	38.4 ± 8.7	39.4 ± 8.6	37.0 ± 7.5	0.3897+ Vs. Placebo 0.4232++	0.1553+ Vs. Placebo 0.3842++
Placebo (Day 30 n=32, Day 60 n=33)	38.8 ± 6.7 38.8 ± 6.6	39.6 ± 9.6	37.0 ± 6.2	0.8737++	0.1170++
Skin barrier function efficacy					
keraGEN IV® (n=30)	9.3 ± 2.7	8.1 ± 2.4	9.5 ± 1.8	0.0135++ * Vs. Placebo 0.3257++	0.6401+ Vs. Placebo 0.2071++
Placebo (n=32, n=33)	8.3 ± 1.6	7.7 ± 2.0	9.0 ± 2.2	0.2130++	0.2318+

** Significant p≤0.05 **Significant p≤0.01 ***Significant p≤0.001*

9.1% perceived a significant improvement, 36.4% felt that their skin had improved and 3.0% felt that their skin had worsened. Overall, the proportion of those taking keraGEN IV® (46.9%) and those taking the placebo (45.5%) who felt some level of improvement in their skin's appearance by the end of the study was virtually the same ($p>0.05$).

3.3.3. Hair self-assessment

Participants had more concerns about the baseline state of their hair relative to their skin, again reflecting study inclusion criteria. None of those in the test group and only 3.1% of those in the control rated their hair strength as good, 62.5% in test and 72.7% in control rated it as average, and 37.5% in the test and 24.2% in the control rated their hair strength as poor. Similar proportions of both groups (46.9% test and 48.5% control; $p>0.05$) perceived that their hair strength had improved to some degree over the course of the study.

At baseline 12.5% of the test and 21.2% of the control rated their hair growth as "good" while 50.0% and 57.6% rated it as average, and 37.5% and 21.2% of the test and control groups, respectively, rated their hair growth as poor. Half of the test and 45.5% of the control groups perceived that their hair growth had improved to some degree over the course of the study, a significant difference at $p\leq0.05$.

Over a third of both the test (37.5%) and control (33.3%) groups rated their hair loss as "poor" at the beginning of the study. By the end, over half of both groups perceived that their hair loss had improved to some level.

Every participant rated their overall hair condition as either "average" (59.4% test, 75.8% control) or "poor" (40.6% test, 24.2% control) at the start of the study. A significantly higher proportion of participants in the study group (9.4%) than in the placebo group (3.0%) perceived that their overall hair condition had significantly improved by the end of the study ($p\leq0.05$).

3.3.4. Nail self-assessment

While 37.5% of those in the test group and 39.4% of those in the control rated their baseline nail strength as "poor," over half (59.4%) of the keraGEN IV® users and 45.5% of those taking the placebo perceived that their nail strength had improved during the 60 days of the study. 56.2% of the test group and 51.5% of those in the control perceived that their overall nail condition had improved while taking the supplements. This evidence does not support that there is a difference in nail self-assessment of either strength or overall condition based on whether the investigational product or the placebo was taken.

4. Discussion and Conclusions

Prior work on keraGEN IV® using in vitro studies on human keratinocytes has shown that increased collagen IV expression is induced by the protein[23]. Further preclinical work using 16 ex vivo skin samples of facial skin removed during a face lift procedure demonstrated that collagen IV expression is induced around the hair follicle[24]. The known function of collagen IV as a junctional pro-

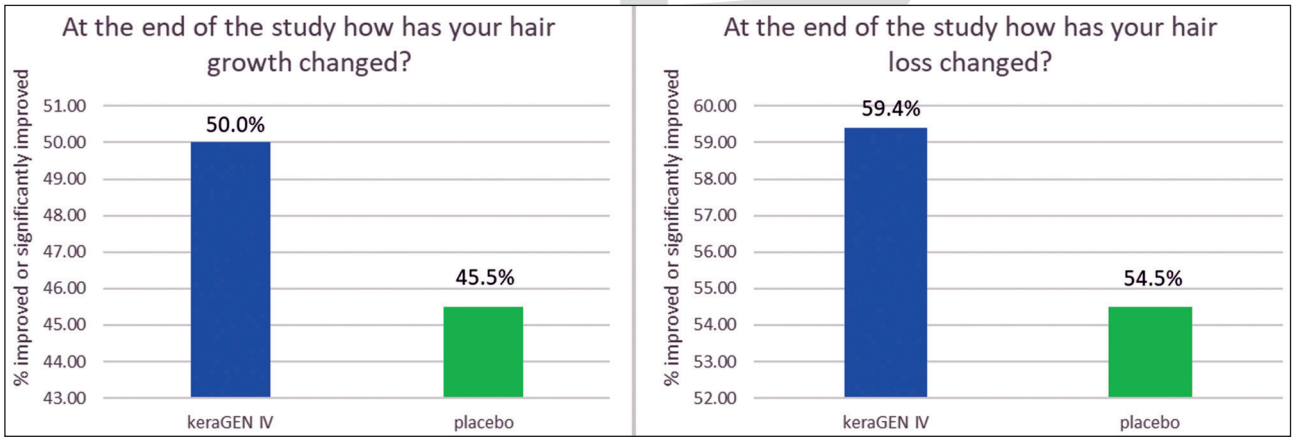

Figure 4. Self-assessment of hair after 60 days of keraGEN IV® or placebo treatment

tein is to build skin structure at the dermal-epidermal junction and further to bind hair follicles as the anchoring protein at the hair root, keeping hair well anchored to the head. This work now demonstrates in a randomised, double blind, controlled study that the keraGEN IV® action of inducing collagen IV expression translates to measurable improvement in hair anchoring, specifically a 43.1% reduction in hair loss in women aged 45-60 with stressed or damaged hair. The gentle pulling action triggering hair loss is typical of that experienced during combing or styling when hair is damaged through chemical treatments, colour, styling or during peri- or post- menopause. The development of healthy hair structure, assisting hair anchoring and importantly improving hair strength, arises from appropriate nutrition including bioavailable cystine and suitable proteins and peptides. The positive impact on cortex structure as a result of keraGEN IV® ingestion is apparent from the improvement in cortex birefringence measured in the study, reinforcing the bioavailable nature of the keraGEN IV® material. Alternative approaches to hair thinning in peri and post-menopausal women have used known anti-inflammatory materials, such as omega 3, omega 6 and lycopene. Published results have demonstrated improvements in follicle density and reduction in hair loss following 6 months intervention[25]. Anti-inflammatory materials impact hair follicle health from different metabolic pathways and may be complimentary to the collagen IV expression induced by keraGEN IV. Examining synergistic effects may be a valuable subject of future investigation.

The measured 12.5% reduction in TEWL may arise from the improvement of skin structure due to collagen IV expression induced by keraGEN IV®. Skin barrier function is an important indicator of skin health. Improvement in skin health and skin structure is also reinforced by the measured improvement in skin elasticity, increasing by 10.1%. Overall, it appears from the study that use of keraGEN IV® results in measurable improvement in skin structure.

COVID-19 has been reported as having a significant impact on hair and nail health, including in combination with isotretinoin therapy[26]. Statistically significant increases in hair loss associated with telogen effluvium have been noted in multicenter studies, as have nail disorders such as leukonychia[27, 28]. Telogen effluvium leads to diffuse hair loss as a result of changes to the growth phase of the hair from anagen to telogen and subsequent changes to hair follicle structure. Although not the subject of this study, increased collagen IV expression around the hair follicle may have an impact on the rate of hair loss following telogen effluvium due to improvement in hair anchoring. The impact of this on the occurrence of diffuse hair loss following COVID-19 is recommended as the subject of future investigation.

Based on the results of this study and recent in vitro and in vivo cytotoxicity assays reporting no adverse effects from keratin supplementation[29], further clinical analysis of keraGEN IV® is warranted. Given that the keratin structure of the hair differs based on ethnicity[30], for example, it would be interesting to expend the study to different ethnic groups. In addition, recruitment criteria included that potential participants had damaged hair but healthy skin; the cause of any nail damage was not investigated. Additional study on the possible effects of keraGEN IV® for those experiencing specific dermatological conditions, and specific nail and hair loss disorders is recommended.

5. References

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