

## Brittle nail syndrome: A pathogenesis-based approach with a proposed grading system

Peter C. M. van de Kerkhof, MD, PhD,<sup>a</sup> Marcel C. Pasch, MD, PhD,<sup>a</sup> Richard K. Scher, MD,<sup>b</sup> Martina Kerscher, MD,<sup>c</sup> Uwe Gieler, MD,<sup>d</sup> Eckard Haneke, MD, PhD,<sup>a</sup> and Philip Fleckman, MD<sup>e</sup>  
*Nijmegen, The Netherlands; New York, New York; Hamburg and Giessen, Germany; and Seattle, Washington*

Brittle nail syndrome is a heterogeneous abnormality, characterized by increased fragility of the nail plate. Brittle nails affect about 20% of the population and women are affected twice as frequently as men. The vast majority of patients experience brittle nails as a significant cosmetic problem and a substantial number indicate that these nail abnormalities are painful, impair daily activities, and may have a negative impact on occupational abilities. Pathogenic factors leading to brittle nails are factors that impair intercellular adhesion of the corneocytes of the nail plate or factors that cause a pathologic nail formation by involving the matrix. Clinical features of brittle nail syndrome are onychoschizia and onychorrhexis: the impairment of intercellular adhesive factors of the nail plate is expressed as onychoschizia, whereas the involvement of the nail matrix is expressed as onychorrhexis. Although impairment of life quality has not been evaluated for patients with brittle nail syndrome, the reduction of life quality in other nail problems has been studied and is evident. A proposed scoring system of key features of brittle nails is presented, and therapeutic approaches focussed on the pathogenic factors are discussed. (J Am Acad Dermatol 2005;53:644-51.)

**B**rittle nail syndrome (BNS) is a heterogeneous abnormality, characterized by increased fragility of the nail plate. About 20% of the population is affected by brittle nails and women are affected twice as frequently as men.<sup>1</sup> The vast majority of patients experience brittle nails as a significant cosmetic problem and a substantial number indicate that these nail abnormalities are painful, impair daily activities, and may have a negative impact on occupational abilities.<sup>2</sup>

In this review pathogenic factors leading to brittle nails will be discussed. Clinical features and aspects of quality of life resulting from this condition will be described and interpreted in the light of our understanding of the pathogenesis. A proposed scoring system of key features of brittle nails will be presented, and therapeutic approaches will be highlighted.

### PATHOGENETIC FACTORS OF BRITTLE NAILS

#### Structure and function of the normal nail plate

The clinical signs of brittle nails reflect pathobiologic changes of the nail plate and nail matrix. The nail plate is largely produced by the nail matrix. About 20% of the nail plate lies beneath the proximal nailfold. The nail matrix is localized under the proximal nailfold; when it extends distal to the proximal nailfold, it is seen as the lunula.<sup>3,4</sup> The nail matrix is continuous with the nailbed. Most of the nail plate is formed by the nail matrix; a small portion of the ventral part of the nail plate is formed in part by the nail bed. Nail growth is between 0.5 and 1.2 mm/wk.<sup>5</sup>

The nail plate normally has a coherent structure, which is characterized by hardness and flexibility. The coherence of the nail plate is the result of intracellular and intercellular structures of the corneocytes forming the nail plate. The organization of keratin filaments within these cells is thought to account for some of the hardness of the nail plate. Radiograph diffraction studies show that keratin fibrils are arranged parallel to the nail surface, perpendicular to the direction of growth of the plate. In contrast to common belief, the calcium content of the nail plate is low ( $\pm 0.2\%$  by weight) and does not contribute to the nail hardness.<sup>6,7</sup> On the other hand, the sulfur content of the nail plate is high ( $\pm 10\%$  by weight); disulfide bonds of cysteine stabilize fibrous proteins and are of relevance to hardness of the nail plate.<sup>7,8</sup>

From the Departments of Dermatology, University Medical Centre St Radboud Nijmegen,<sup>a</sup> and Columbia University Medical Center, New York<sup>b</sup>; Department of Cosmetic Sciences, University of Hamburg<sup>c</sup>; Department of Psychosomatic Dermatology, Justus-Liebig-University, Giessen<sup>d</sup>; and Division of Dermatology, University of Washington.<sup>e</sup>

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Reprint requests: Prof. dr. Peter C. M. van de Kerkhof, Department of Dermatology, University Medical Centre St Radboud, PO Box 9101, 6500 HB Nijmegen, The Netherlands.

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The nail plate contains about 10% to 15% water.<sup>9,10</sup> The relatively low lipid content of the nail plate (<5%) implies that water permeation through the plate is relatively high as compared with the stratum corneum.<sup>9,11</sup> Hence, the capacity of the nail plate to maintain a hydrated state is low as compared with the stratum corneum.<sup>12</sup> However, results from *in vitro* and *in vivo* investigations of nails by NIR-FT-Raman spectroscopy indicate that the mechanical properties of the nails are related to the water content of the nail plate.<sup>13</sup>

Critical to the coherence of the nail plate is the: (1) structure of keratin fibrils (the intracellular skeleton); (2) keratin associated proteins, which are thought to form the matrix between keratin filaments; (3) lipid bilayers; and (4) desmosomes. Environmental factors (chemical and mechanical) may damage these structures and, hence, cause brittle nails.<sup>4,12,14,15</sup>

The formation of the nail plate requires epidermal proliferation of both the matrix and the nail bed. This process involves recruitment of cycling epidermal cells from the resting G<sub>0</sub> population. The process of epidermal differentiation involves terminal differentiation with formation of layers of corneocytes. Nail growth is highly dependent on vascularization and inflammation.<sup>4,16</sup> Systemic factors may affect nail growth, including oxygenation, endocrine and metabolic factors, and serious infectious diseases.<sup>4,16</sup> Recently, factors influencing nail growth have been reviewed by Geyer et al.<sup>17</sup> In addition, abnormalities in the consistency of the nail plate caused by abnormal production and differentiation of corneocytes may predispose to damage by external factors, impairing the coherence of the nail plate. Furthermore, reduced growth rate of the nail plate may prolong expose of the nail plate to external damaging factors.

### Impairment of intercellular adhesive factors of the nail plate

Exogenous factors may damage the coherence of the nail plate by interfering with the intercellular adhesive factors (Table I). Hydration and desiccation of the nail plate may change with the seasons and may play a significant role in occupations such as household help, nursing, and hairdressing, where repetitive wetting and drying of the hands results in contraction and expansion of the nail, leading to fractures between nail plate corneocytes.<sup>18,19</sup>

In particular, occupational exposure to chemicals, thioglycolates, cement, solvents, alkalis, acids, anilines, salt, and sugar solutions may dissolve intercellular lipids and, hence, damage intercellular cohesion causing fractures between corneocytes.<sup>16-22</sup> In addition, cosmetics, especially nail enamel re-

**Table I.** Impairment of intercellular adhesive factors of the nail plate

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A. Exogenous factors  
Immersion/desiccation  
Chemicals  
Trauma  
Fungi

B. Secondary to pathologic nail formation

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movers/solvents, nail hardeners, cuticle removers, and special nail procedures like nail wrapping, nail sculpturing, application of premixed acrylic gels, and an excessive and/or incorrect use of manicure tools may cause intercellular fractures of the nail plate.<sup>23</sup>

Interactive trauma of the fingernail (for example typing, telephone dialing, improper nail clipping, and trauma caused by excessive length of the nails) may damage the nail plate and cause fractures between corneocytes.<sup>4</sup> Fungal infections may result in both intracellular and intercellular fractures in the nail plate by proteolytic activity.<sup>18,19</sup>

The above-mentioned external factors may be harmful particularly for those nails with reduced growth rate, as the cumulative exposure time to external damage is increased. In 77% of patients with brittle nails, sulfur content was decreased, which implies fewer disulfide bridges among proteins forming keratin fibrils.<sup>24</sup> An age-associated decrease of cholesterol sulfate concentration in nail clippings of women has been reported.<sup>25</sup> This decrease might represent a predisposition for brittle nails, which has been reported to be more frequent in the elderly and women. Investigations of the water-binding capacity of brittle nails shows that slices of brittle nail increase less in thickness after exposure to alkali as compared with normal nail.<sup>26</sup> The water-binding capacity of the brittle nail is less when compared with normal nail, which may reflect an abnormality of keratin, keratin-associated proteins, lipid content, or a combination of these. The concentration of the trace elements Ca, Mg, Al, Cu, Zn, and Fe in brittle nails is not significantly different from the concentration in normal nails.<sup>5,27</sup>

### Pathologic nail formation

Epithelial growth and keratinization in the nail matrix and to a lesser extent in the nail bed are responsible for the formation of a healthy nail. Impairment of these processes is expressed as a focal or longitudinal nail plate abnormality, depending on the duration of the pathologic process. Long-term focal increases in nail production in the matrix

**Table II.** Causes of pathologic nail formation

Decreased nail formation after radiation or arsenic intoxication
Decreased vascularization
Arteriosclerosis
Raynaud's disease
Decreased oxygenation
Anemia
Polycythaemia vera (sludging)
Major chronic infections
Sarcoidosis
Endocrine diseases
Metabolic diseases
Disordered keratinization
Inflammatory diseases
Disorders of cornification
Neoplasias

will cause longitudinal ridges and long-term focal decreases in nail formation or foci of abnormal keratinization will cause longitudinal splits and canaliculi such as occurs in lichen planus. Generalized, transient slowing down of nail production results in transverse furrows Reil-Beau's lines. Vascularization and oxygenation of the nail matrix have an important impact on epidermal growth and keratinization in the nail matrix. Metabolic and nutritional factors also may interfere with growth of the epidermis and keratinization. Pathologic involvement in disorders of keratinization has a direct impact on nail formation. Table II summarizes these influences. Recently, diseases with decreased and enhanced nail growth have been reviewed.<sup>17</sup>

Decreased nail growth and abnormal keratinization may result from previous irradiation or arsenic use.<sup>20,28</sup> Pathologic nail formation has been associated with endocrine and metabolic diseases such as hypopituitarism, hypothyroidism and hyperthyroidism, hypoparathyroidism, acromegaly, diabetes mellitus, gout, osteoporosis, osteomalacia, arginosuccinic aciduria, pregnancy, and malnutrition (anorexia nervosa, bulimia).<sup>13,17,18,20,29-31</sup> Direct evidence that these disorders decrease nail growth or affect keratinization is not available. However, the processes of epidermal growth and keratinization are highly dependent on hormonal control (retinoids, vitamin D<sub>3</sub>, calcium homeostasis, and growth hormones).

As vascularization and oxygenation directly affect epidermal growth and keratinization, arteriosclerosis and age-related decrease of circulation, microangiopathy, Raynaud's disease, anemia, polycythaemia vera (polycythaemia causing sludge formation),<sup>18,19,28,32-34</sup>



**Fig 1.** Mild brittle nails: mild distal lamellar splitting (grade 1) and mild longitudinal ridging (grade 1).

major chronic infectious diseases (pulmonary tuberculosis, empyema, bronchiectasis), and sarcoidosis all may impair nail formation.<sup>35,36</sup>

### Disorders of the process of keratinization

Disordered keratinization may impair nail plate formation. In the case of a self-limiting impairment of short duration, nail pits or spots of leuconychia may be seen. The entire nail plate or longitudinal involvement results from pathologic processes that have impaired the nail matrix during prolonged periods. For example Darier's disease, pityriasis rubra pilaris, lichen planus, and alopecia areata may cause longitudinal ridges, longitudinal splits, or sandpaper-like nails. Psoriasis, atopic dermatitis, and mycoses may cause thickening of the nail plate with a brittle appearance. Nail tumors (such as melanoma, squamous cell carcinoma, warts, and granuloma pyogenicum) are diagnosed after removal of the nail plate, but the nail plate may show longitudinal abnormalities indicative of brittleness.

Usually disorders that alter keratinization can be diagnosed as separate entities, distinct from brittle nails, although features of brittle nail characterize to some extent the nail plates in these patients.

### CLINICAL FEATURE OF BNS SIGNS AND SYMPTOMS AND A PROPOSED GRADING SYSTEM

The changes associated with brittle nails are subjective and, therefore, difficult to quantify. Because of this, we propose the following semiquantitative grading system. Disease severity may be specified according to various signs and symptoms or an average score may be calculated. Figures 1-3 illustrate various degrees of severity of brittle nails.

### Onychoschizia

The impairment of intercellular adhesive factors of the nail plate is expressed clinically as onychoschizia,



**Fig 2.** Moderate brittle nails: moderate lamellar crenelated splitting (grade 2), moderate longitudinal, ridging (grade 2) and longitudinal splitting (grade 2), moderate thickening of nail plate (grade 2).



**Fig 3.** Severe brittle nails: severe lamellar splitting (grade 3) and moderate longitudinal ridges (grade 2), longitudinal splitting (grade 2), and moderate thickening (grade 2).

which is characterized by lamellar splitting of the free edge and distal portion of the nail plate. The severity of lamellar splitting may vary from mild parallel furrows of the superficial layers of the back surface of the nail plate at the distal free edge to severe lamellar splitting of the complete free edge and at least one third of the distal part of the nail plate. Proposed grades of severity of lamellar splitting are given in Table III. Onychoschizia may also include breaking of the lateral edges, causing transverse splitting. The severity of transverse splitting may vary between a single, superficial horizontal split of the nail plate to multiple horizontal splits leading to loosening of at least one third of the distal nail plate (Table IV).

Onychoschizia also can be evaluated in vivo non-invasively through means of 20-MHz ultrasound measurements. Mild onychoschizia will result in an extension of the entry echo in the scan (Fig 4), whereas moderate to severe onychoschizia is visible as an extended and highly irregular entry echo (Fig 5). Furrows clinically associated with onychoschizia

**Table III.** Proposed score for lamellar splitting

**Lamellar splitting defined as onychoschizia**

- 0 = None, clear of clinical signs of lamellar nail splitting
- 1 = Mild, distal furrows, parallel to the back surface, not involving the entire free edge of the nail plate
- 2 = Moderate, distal parallel furrows of the superficial nail plate involving the complete free edge of the nail plate
- 3 = Severe, distal lamellar splitting of the complete free edge of the nail plate, lamellar splits covering at least one third of the nail plate.

**Table IV.** Proposed score for transverse splitting

**Horizontal nail splitting from the free edge of the nail plate**

- 0 = None, clear of clinical signs from the free edge of the nail plate
- 1 = Mild, one superficial horizontal split of the distal nail plate
- 2 = Moderate, 2 or 3 horizontal splits of the distal nail plate
- 3 = Severe, multiple horizontal splits leading to loosening of at least one third of the distal nail plate

can be seen in the ultrasound image as narrowing of the entry echo (Fig 4).

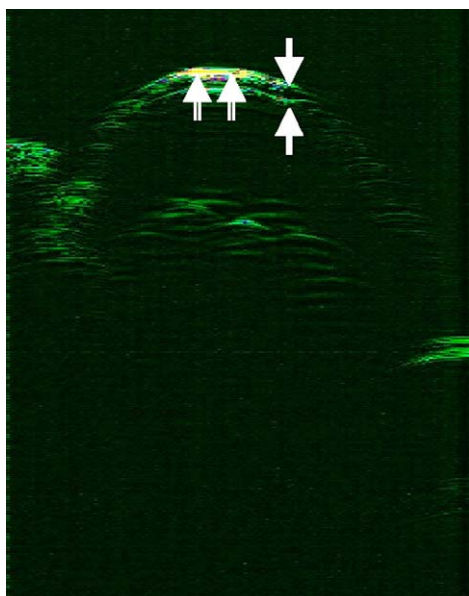
The causes of onychoschizia consist of external factors that dissolve or break the coherence between corneocytes. Chemical and/or mechanical factors have to be reconciled (Table I). In case of onychomycosis the lateral and medial edges of the nail plate may show typical yellow, red, and brown discoloration and have a brittle appearance; sometimes the entire nail plate has a rough appearance, and signs of onychoschizia may be seen.

**Onychorrhaxis**

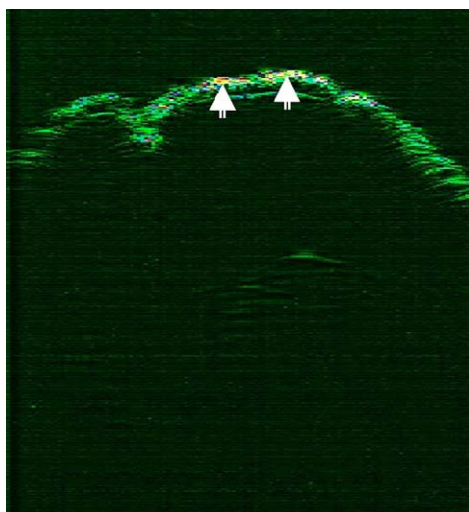
The involvement of the nail matrix is expressed clinically as onychorrhaxis. Onychorrhaxis is characterized clinically by longitudinal thickening and thinning or ridging of the nail plate. Longitudinal ridges may vary from a few plane ridges up to multiple deep ones, covering at least 70% of the nail surface. Longitudinal splitting also may vary from a few superficial splits up to multiple superficial and deep ones. Tables V and VI summarize proposed severity scores for longitudinal ridging and splitting and Table VII provides the proposed severity score for thickening.

Other hallmarks for onychorrhaxis may be crinolated, multiple splits, characterized by triangular fragments at the free edge that can be torn off easily. Abnormalities in epidermal growth and keratinization may result in onychorrhaxis. Table I





**Fig 4.** A 20-MHz ultrasound image of moderate brittle nail: enlarged entry echo (*double arrows*). On right side, depression of entry echo (*arrows*) because of longitudinal furrow.



**Fig 5.** A 20-MHz ultrasound image of severe brittle nail: enlarged and very irregular entry echo (*arrows*) because of severe brittleness of nail plate.

summarizes various factors that may induce the dysregulation of growth and keratinization underlying onychorrhexis. Endocrine and metabolic causes and abnormalities of vascularization and oxygenation may underlie the disordered keratinization responsible for onychorrhexis.

When disordered keratinization causes onychorrhexis, other clinical signs will often give away the diagnosis. Longitudinal ridges and splitting are a hallmark for lichen planus and pityriasis rubra

**Table V.** Proposed score for ridging

**Assessment of ridges and longitudinal grooves**

- 0 = None, clear of any signs of ridging and longitudinal grooves
- 1 = Mild, few plane ridges and longitudinal grooves
- 2 = Moderate, few deep ridges and longitudinal grooves
- 3 = Severe, more than 70% of the nail plate showing deep ridges and corresponding grooves

**Table VI.** Proposed score for longitudinal splitting

**Longitudinal splitting as derived from the nail matrix and defined as onychorrhexis**

- 0 = None, clear of clinical signs of longitudinal nail splitting
- 1 = Mild, one single, superficial longitudinal split of the nail plate
- 2 = Moderate, at least one deep longitudinal split of the entire nail plate
- 3 = Severe, multiple, superficial and deep longitudinal splits of the nail plate

**Table VII.** Proposed score for nail thickness

**Deviation from normal nail thickness regardless of thinning or thickening of the nail plate**

- 0 = None, normal thickness of the nail plate
- 1 = Mild thinning or thickening of the nail plate
- 2 = Moderate, clearly visible change in nail thickness
- 3 = Severe, obvious change in nail plate thickness at least doubling or halving nail thickness

pilaris. Pterygium formation and typical papules of lichen planus and the pathognomonic features of the mucosal membranes will reveal the diagnosis. In pityriasis rubra pilaris splitting may be absent or minimal and typical follicular papules will suggest the diagnosis. In psoriasis and alopecia areata, classic nail pathology and diagnostic skin lesions usually lead to the diagnosis. However, in the case of severe nail involvement in these disorders, the nails may look brittle and may have longitudinal ridging and splitting, which can justify only the morphologic diagnosis of onychorrhexis. Onychorrhexis may complicate the picture of squamous cell carcinoma of the nail matrix. Metabolic, endocrine, vascular, and pulmonary diseases have to be considered as well in onychorrhexis (Table II).

**Differential diagnosis of BNS**

In clinical practice onychophagia may be a cause of brittle nails. The majority of cases are considered mild and cosmetic, but nevertheless lead to serious morbidity.<sup>37</sup> Nail damage such as scarring, infection,

and bleeding may result in brittle nails. The cause of this condition is usually psychogenic. Another aspect of brittle nails in this category may be seen in eating disorders such as anorexia and bulimia, especially during childhood and adolescence.<sup>38</sup> The combination of brittle nails and dyspareunia may be a first clue for a malignant glucagonoma.<sup>39</sup>

### Life quality and psychosocial impairment

Healthy looking nails are important for a well-groomed appearance. Multifactorial features are important to the appearance of an aesthetic nail: length/shape, color, surface texture, and peri-onychial integrity.<sup>40</sup> Brittle nails might lower self-esteem. Although impairment of life quality has not been evaluated in patients with BNS, the reduction of life quality in nail problems such as psoriasis<sup>41</sup> or onychomycosis are evident. In a study with 1728 patients with psoriasis, 51.8% had pain caused by the nail changes and most of them were restricted in their daily activities.<sup>41</sup> It is well-known that self-esteem and social interactions are adversely affected in patients with onychomycosis. A health-related quality-of-life measure for patients with onychomycosis<sup>42</sup> demonstrated significant pain and discomfort. An international study in onychomycosis<sup>43</sup> showed a correlation of life quality reduction with longer duration of disease, greater involvement with more serious adverse effects, and greater number of nails involved. Another study in 258 patients<sup>44,45</sup> pointed out that 76% had nail-trimming problems, 74% embarrassment and pain, and nail pressure and discomfort wearing shoes. Elewski<sup>46</sup> showed in 93 patients with onychomycosis that 92% reported negative psychosocial and/or physical effects and 44% had a negative self-image.

### Therapeutic approaches

Therapeutic approaches to brittle nails depend on whether they are characterized mainly by onychoschizia or onychorrhexis. First, eliciting factors need to be identified and eliminated. After that, general principles of nail care can be advised and more specific therapies used.

### Eliciting factors

In cases of onychoschizia, immersion/desiccation should be avoided. In certain professions the degree of water immersion should be reduced by using gloves. Where there is occupational exposure to chemicals, wearing gloves is essential. In professions with repeated trauma to the nails, the nails should be clipped short. In general, short nails minimize microfractures that give rise to onychoschizia. Clipping results in regular free edges when done

after soaking in water. When signs of fungal infection exist antimycotic treatment is indicated. Onychoschizia can be secondary to onychorrhexis and in such a situation the eliciting factors should be eliminated.

For patients with onychorrhexis damage to the nail matrix from arsenic and irradiation and factors involving microcirculation and oxygenation should be excluded. Systemic diseases, and metabolic and nutritional disorders should be looked for, and primary dermatologic conditions that directly influence nail matrix function must be excluded.

General therapeutic principles for onychoschizia and onychorrhexis involve increasing the water content and decreasing irregularities of the nail. The water content may be increased by soaking 15 minutes every evening. Applying emollients, especially those containing phospholipids, significantly improves nail hydration.<sup>47,48</sup> Nail hardening agents, particularly those containing formaldehyde, may be useful to strengthen the nail plate but should be used cautiously, as they may also lead to brittleness, onychoschizia, onycholysis, and subungual hyperkeratosis.<sup>4</sup> Application of enamel will protect the nail mechanically, may improve the water binding of the underlying nail, and may be used to fill in fractures, but the use of enamel removers is likely to increase dehydration substantially.<sup>48</sup>

Specific therapeutic approaches to onychoschizia are focused on preservation of nail integrity. Thus, increasing the water content, gluing fractures and splits with acrylic glues, and nail hardening agents remain the most important approaches together with prevention of external damage. In the case of onychorrhexis the eliciting factors should be corrected. However, the need for additional, more effective therapy remains. About half a century ago, it was suggested that large amounts of gelatin increase cystine content,<sup>49,50</sup> which may reflect keratin formation and cross-linking, but there are no data to confirm these speculations. Biotin has been shown to be a beneficial therapy.<sup>51</sup> In one study, biotin (2.5 mg/d) for 6 to 15 months improved brittle nails; nail thickness improved by 25% and lamellar splitting improved in all patients.<sup>51</sup> In another study, biotin (2.5 mg/d) for 1.5 to 7 months resulted in clinical improvement in 67% of the patients.<sup>52</sup> However, both studies were carried out in small groups of patients without a control group. The daily requirement of biotin is unknown because it is produced in large quantities by intestinal bacteria.

The treatment of brittle nails is never easy. There remains a large, unmet need for approaches aimed at recovery of intercellular adhesion of corneocytes

and better nail unit function that results in improvement in quality of life.

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