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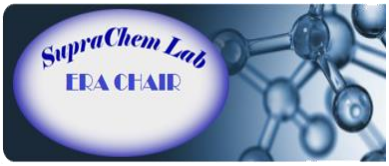

Nail Damage (Severe Onychodystrophy) Induced by Acrylate Glue: Scanning Electron Microscopy and Energy Dispersive X-Ray Investigations

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Abstract

Background

Scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) techniques have been used in various fields of medical research, including different pathologies of the nails; however, no studies have focused on obtaining high-resolution microscopic images and elemental analysis of disorders caused by synthetic nails and acrylic adhesives.

Methods

Damaged/injured fingernails caused by the use of acrylate glue and synthetic nails were investigated using SEM and EDX methods.

Results

SEM and EDX proved that synthetic nails, acrylic glue, and nails damaged by contact with acrylate glue have a different morphology and different composition compared to healthy human nails.

Conclusions

SEM and EDX analysis can give useful information about the aspects of topography (surface sample), morphology (shape and size), hardness or reflectivity, and the elemental composition of nails.

Key Words: Acrylate glue, Onycholysis, Scanning electron microscopy, Synthetic nails

Introduction

Nails can be affected by natural factors, such as aging and infections, but also by chemical factors, such as most solvents found in nail polish and detergents [1].

Applied acrylic nails in conjunction with adhesives increase the bond between the natural nail and the synthetic one causing an alteration in nail flexibility, composition, and morphology. Rigidly adhered acrylics may also lead to serious breaking of nails, infection, and loss of the natural nail [2]. Allergic reactions to acrylic nails have also been reported, resulting in serious inflammation and thinning of the nail beds [3,4].

Scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) techniques are widely used in crystallography, geology, biology, medicine, nonbiological sciences, and other fields [5]. In recent years, EDX/SEM systems have become more and more attractive for the nanoscale investigation of biological structures in various medical fields (pathology of the heart [6,7], kidney [8,9], skin [10,11], and hair [12,13,14]).

SEM is a noninvasive technique which can be used for micro- and nanoscale observation and the characterization of inorganic or organic solids (revealing the microstructure, morphology, and fracture topography) [5,15,16,17], while the SEM technique can be used for the investigation of cells [18], tissues [5,14,19,20], fragments of organs, or even organisms of suitable size [21,22].

EDX is an analytical technique used for the elemental analysis or the chemical characterization of a sample, as well as in conjunction with the SEM technique [23]. EDX can only determine elements with an atomic number >5, but it is a versatile technique and allows gathering information about the distribution of chemical elements and the concentration profile of an element along a direction of interest in the sample; characteristics of the EDX spectrum of

a sample can allow the calculation of the chemical composition. EDX has already become a useful research tool in the investigation of biological tissue surfaces [24,25,26,27,28,29].

Materials and Methods

A 24-year-old female presented to the Dermatology Department for severe degradation of the nail plates of all digits. The patient had no history of atopic dermatitis or allergic reactions, and no recent drug intake. Artificial nails had been applied, for the first time, a few days prior to the medical examination.

Clinical examination revealed severe degradation of the nail plates of all fingernails, associated with intense pain, slight pruritus on the tips of the digits, and paronychia (fig. 1). Full blood count was normal, and C-reactive protein level, erythrocyte sedimentation rate, urea, electrolytes, liver function tests, as well as urine analysis were within normal limits; screening for hepatitis virus B and C was negative. Mycological examination and fungal culture of scrapings from nail plates were repeatedly negative. The patient did not approve of nail biopsy due to intense local pain and anxiety. Patch tests with extended European Baseline Series and with methyl methacrylate 2% and toluenesulfonamide formaldehyde resin 10% (Chemotechnique) were negative.

Fig. 1. Nails of the female patient damaged by acrylate nail glue.

Slight improvement was obtained with systemic antihistamines, potent topical steroid cream, and removal of the artificial nails. The patient was followed up for 3 months with full recovery.

The analysis of the damaged fingernail was compared to a healthy nail taken from a donor of the same age and gender, using SEM and EDX techniques.

SEM and EDX Analysis

Morphological studies were performed using a Quanta 200 SEM equipped with an Oxford INCA EDX system. In order to prepare samples for SEM and EDX, small cuttings from the control nail as well as from the synthetic and damaged nails of the patient were deposited on aluminum stubs with double-sided carbon tape. Investigations were performed in low vacuum mode using a secondary electron detector (large field detector) at an accelerating voltage of 10 kV. Samples were prepared by cutting pieces of nails in squares of 2 × 2 mm.

Results

SEM analysis of the nail affected by acrylate glue (fig. 2a), a piece of the damaged nail glued to the synthetic one (fig. 2b), the healthy human control nail (fig. 2c), and the synthetic nail (fig. 2d) was performed in order to evaluate the changes induced by applying acrylate adhesive on the human nail. Elemental analysis was obtained by the EDX method, as shown in figure 3.

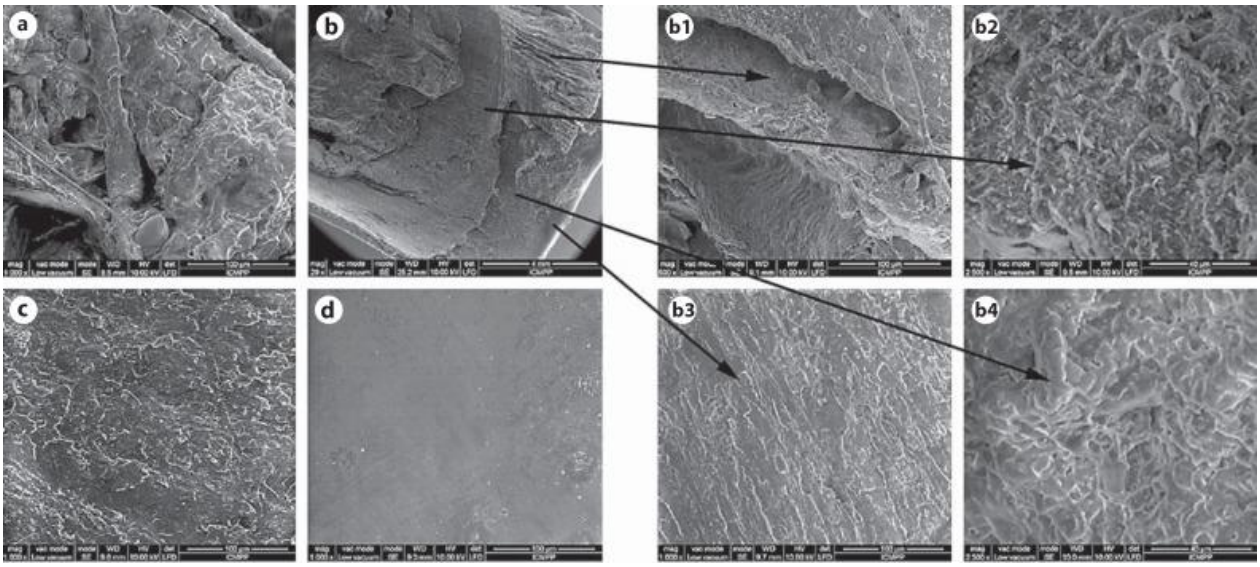

Fig. 2. SEMs of the nails. **a)** Affected dorsal human nail due to acrylate glue. **b)** A piece of damaged nail glued to the synthetic one. **c)** Healthy human nail. **d)** Synthetic nail. **Insets for b**: the intermediate layer (**b1**), the bottom layer (**b2**), the synthetic nail area (**b3**), and the glue area (**b4**).

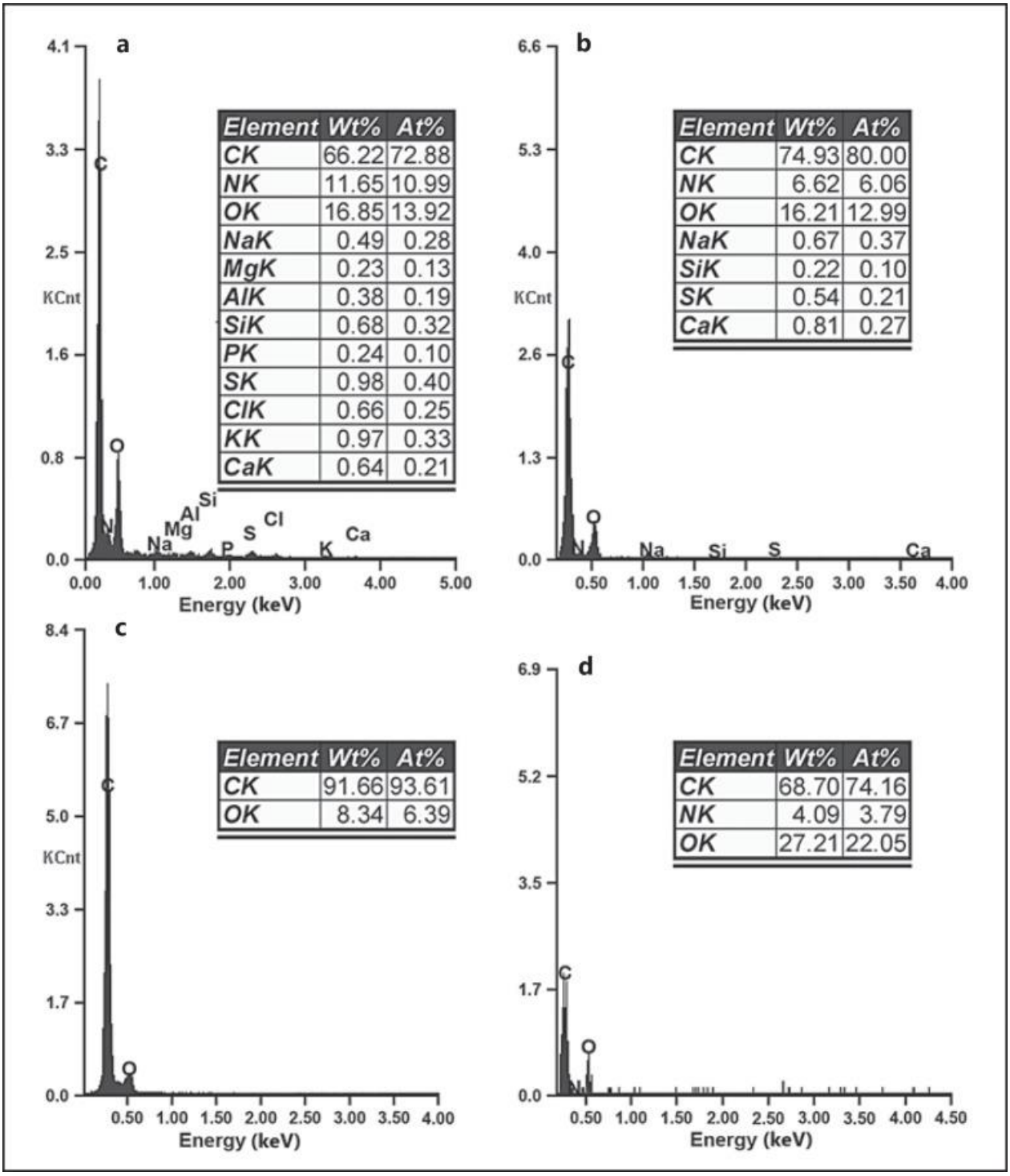

Fig. 3. EDX spectra of the nails. **a)** Healthy human nail. **b)** Layer of damaged human nail. **c)** Synthetic nail. **d)** A piece of the damaged nail glued to the synthetic one.

Discussion

Recent studies have shown that acrylic nails and adhesives may induce fingertip and periungual dermatitis, onycholysis, and nail dystrophy [3,4], as well as allergic reactions [30].

The present study investigated the effects induced by acrylic glue, which was applied to stick the synthetic nail to the normal human one.

SEMs at the same magnification of the affected nail of the patient (fig. 2a) and the piece of the damaged nail glued to the synthetic one (fig. 2b) compared to those of the normal (fig. 2c) and synthetic (fig. 2d) nails clearly reveal that the morphology is dramatically changed due to the aggressive action of acrylic adhesive on fingernails.

The SEM image of the affected nail appears to be rough, with globular domains (fig. 2a), while the healthy nail (fig. 2c) is uniform, composed of flat, overlapping slate-like sheets oriented in the plane of the nail, with only occasional separation of one or more corneocytes [31]. The surface of the synthetic acrylic nail (fig. 2d) has a different morphology compared to the damaged and normal nails, showing a flat layer with rare globular domains. A close examination of the piece of damaged nail glued to the synthetic one (fig. 2b), in different areas, highlighted the fact that an intermediate layer presents a fibrillar morphology (fig. 2b1) and the bottom layer presents tile-like cells with randomly oriented fibrous keratin (fig. 2b2). SEMs of the synthetic nail (fig. 2b3) and glue (fig. 2b4) show amorphous morphology with weak globular domains, similar to the synthetic nail alone (fig. 2d).

EDX analysis of the synthetic nail (fig. 3c) only shows 2 elements, while the normal nail reveals the presence of 12 elements in different concentrations (fig. 3a): carbon (C) 72.88% (atomic concentration), oxygen (O) 13.92%, nitrogen (N) 10.99%, sodium (Na) 0.28%, magnesium (Mg) 0.13%, aluminum (Al) 0.19%, silicon (Si) 0.32%, phosphorous (P) 0.10%, sulfur (S) 0.40%, potassium (K) 0.33%, calcium (Ca) 0.21%, and chlorine (Cl) 0.25%.

The elemental analysis of the synthetic nails only showed 2 major elements: C (93.61%) and O (6.39%) (fig. (fig.3c3c).

The damaged nail had a different composition (fig. 3b), containing C (80.00%) as the dominant element, as well as O (12.99%), N (6.06%), Na (0.37%), Si (0.10%), S (0.21%), and Ca (0.27%). The concentration of Na was increased in the damaged nail, Al was absent (possibly correlated with the less hardening nail) [32], whereas the concentrations of Si and S were low. The diminished content of S in the injured nail may be explained by the action of chemical compounds that can cause the destruction of the nail, attacking the disulfide bridges, which are responsible for the stability of keratin nail matrix (fig. 4). Nail keratin contains cysteine (fig. 4a), which is responsible for the stability of the nail matrix along with the inter- and intramolecular hydrogen bonds produced by amide groups of keratin [33].

In the present case, disulfide groups of cystine units were transformed by reduction reactions in thiol groups of. cysteine (fig. 4b); some of them were oxidized to sulfate groups of cysteic acid (fig. 4c) and later to volatile degradation products, such as hydrogen sulfide (SH_2) (fig. 4d) [34]. As a consequence of these reactions, the stability of the nail was reduced and the content of S decreased.

Elemental analysis and EDX spectra of the damaged nail glued to the synthetic one (fig. 3d) proved the presence of C and O elements in high concentrations and of N in a lower amount. The presence of N was the indication that the nail piece was glued to the artificial fingernail through the acrylic adhesive.

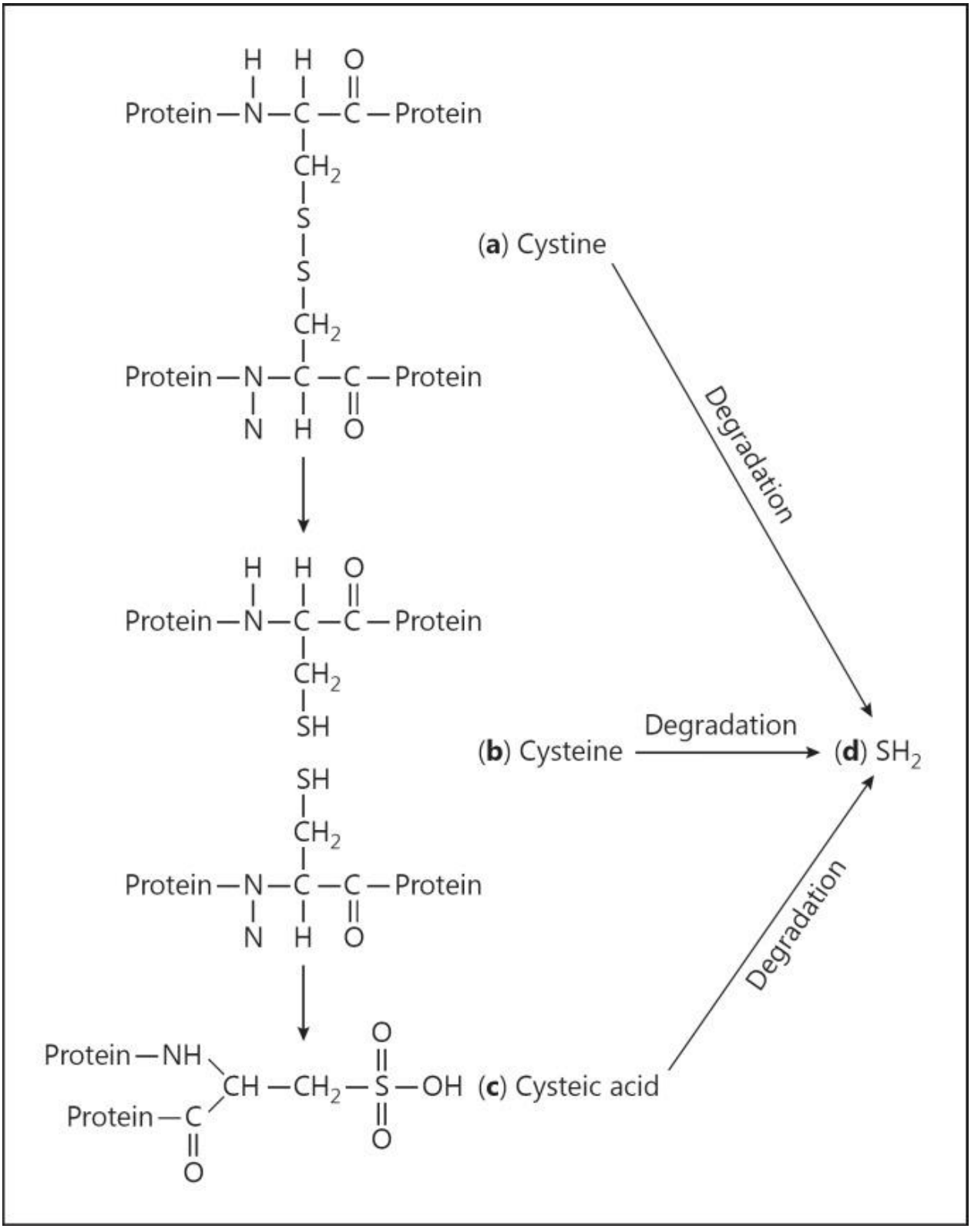

Fig. 4. The principal keratin structural units and the schematic mechanism of disulfide bridge degradation. This figure shows cystine **(a)**, cysteine **(b)**, cysteic acid **(c)**, and the degradation of cystine, cysteine, and cysteic acid **(d)**.

Conclusions

EDX and SEM methods were used in a case of severe degradation of nail plates induced by contact with acrylic nail glue comparing normal and synthetic nails.

The results obtained by EDX and SEM methods were complementary and consistently demonstrated that: (a) acrylate nail glue, in particular, produces degradation of the disulfide bridge of cystine units from protein to thiol groups, and some of them into sulfite groups or a complete degradation, producing a destabilization of the healthy nail matrix with changes in surface morphology in terms of uniformity, density, and roughness; (b) acrylate nail glue causes loss of Si (reducing brightness), which increases the content of Na and Ca; and (c) loss of Al (indicating less nail hardening).

We present a case of acute and severe degradation of nail plates by direct contact with acrylates in the absence of any allergic reactions. EDX and SEM proved that the nail degradation was induced by contact with acrylate nail glue. Further studies using the same methods with different nail pathology could be of great value for a diagnosis and understanding of the mechanisms of nail destruction.

Statement of Ethics

Written informed consent was obtained from the patient, and the study was performed according to the Declaration of Helsinki.

Disclosure Statement

The authors declare no conflicts of interest.

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