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Onychomycosis in the elderly. Interdisciplinary cooperation between dermatologists and podiatrists

Grzybica paznokci u osób starszych – znaczenie współpracy interdyscyplinarnej między dermatologami a podologami

ABSTRACT

Introduction: Onychomycosis is a common fungal nail infection that poses a significant therapeutic challenge, particularly in the elderly population. The use of pharmacological monotherapy alone is often insufficient.

Aim: The study aimed to present the course of diagnostic and therapeutic management in a man with onychomycosis of rare yeast etiology.

Materials and methods: A 92-year-old man was diagnosed with a severe fungal infection of the left big toenail caused by an atypical yeast-like pathogen of the genus *Rhodotorula*. Combination therapy was administered, consisting of systemic pulse therapy with itraconazole and podiatric procedures. Changes in the color and texture of the nail plate were assessed using digital image analysis.

Results: After four cycles of pulsed itraconazole therapy and three sessions of mechanical nail plate treatment, clinically visible lesions resolved.

Conclusions: The combination of systemic itraconazole therapy with mechanical nail plate treatment was associated with clinical improvement. Collaboration between a dermatologist and a podiatrist may serve as a complementary component of management in elderly patients. Digital analysis of color and texture parameters may support photographic documentation; however, its usefulness as a tool for assessing treatment efficacy requires further validation.

Keywords: onychomycosis, *Rhodotorula* spp., podiatrist, nail fungus, nail plate deformities, pharmacotherapy.

STRESZCZENIE

Wprowadzenie: Onychomikoza jest powszechną chorobą grzybiczą paznokci, stanowiącą istotne wyzwanie terapeutyczne, szczególnie w populacji osób w podeszłym wieku. Stosowanie samej monoterapii farmakologicznej bywa niewystarczające.

Cel: Celem pracy było przedstawienie przebiegu postępowania diagnostyczno-terapeutycznego u mężczyzny z onychomikozą o rzadkiej etiologii drożdżakowej.

Materiały i metody: U 92-letniego mężczyzny zdiagnozowano ciężką infekcję grzybiczą paznokcia palucha lewego wywołaną przez nietypowy drożdżopodobny patogen z rodzaju *Rhodotorula*. Zastosowano terapię skojarzoną obejmującą ogólnoustrojową terapię pulsową itrakonazolem oraz procedury podologiczne. Dokonano oceny zmian parametrów barwy i tekstury płytki paznokciowej za pomocą cyfrowej analizy obrazu.

Wyniki: Po zastosowaniu czterech cykli terapii pulsowej itrakonazolem oraz trzech zabiegów mechanicznego opracowania płytki uzyskano ustąpienie widocznych klinicznie zmian chorobowych.

Wnioski: Skojarzenie terapii ogólnej itrakonazolem z mechanicznym opracowaniem płytki paznokciowej wiązało się z poprawą kliniczną. Współpraca dermatologa i podologa może stanowić uzupełniający element postępowania u pacjentów w podeszłym wieku. Cyfrowa analiza parametrów barwy i tekstury może wspomagać dokumentację fotograficzną, jednak jej przydatność jako narzędzia oceny skuteczności leczenia wymaga dalszej walidacji.

Słowa kluczowe: onychomikoza, *Rhodotorula* spp., podolog, grzybica paznokci, deformacje płytki, farmakoterapia.

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INTRODUCTION

Onychomycosis is one of the most common nail infections, accounting for approximately 50% of all nail plate pathologies and up to 30% of skin infections caused by dermatophytes [1-3]. This condition is chronic, progressive, and often recurrent, significantly impacting patients' quality of life [4]. Due to the increasing prevalence of this disease among the elderly, diabetic patients, and immunocompromised individuals, effective treatment of onychomycosis has become a major therapeutic challenge [5, 6].

Systemic antifungal pharmacotherapy, primarily based on the oral administration of terbinafine [7-10] or itraconazole [11-14], constitutes the cornerstone of treatment for moderate to severe forms of onychomycosis, tailored according to the pathogen profile, extent of nail apparatus involvement, potential drug interactions, and the patient's internal medical comorbidities.

The presence of hyperkeratosis, subungual keratosis, and nail plate deformities can impair drug penetration and lead to recurrence. Consequently, in recent years, attention has increasingly focused on integrated treatment models that combine systemic or topical therapy with routine nail care and mechanical or chemical debridement of lesions [15-17].

The dermatologist plays an essential role in diagnosis, differential diagnosis, and pharmacotherapy management, while the podiatrist is responsible for lesion debridement, reduction of hyperkeratosis, and supportive topical treatment. The 2006 randomized IRON-CLAD trial conducted by Jennings et al. [18] confirmed that combining systemic therapy with aggressive nail debridement yields higher treatment efficacy, demonstrating a significantly higher rate of clinical cure compared to antifungal monotherapy [19]. Although this study evaluated a specific procedural protocol, it provided grounds for the hypothesis that collaboration between a dermatologist (responsible for medical diagnosis and pharmacotherapy) and a podiatrist (performing routine care and mechanical tissue debridement within their professional competencies) can optimize patient management [20-22].

AIM

This study aimed to present the course of integrated dermatological and podological management in a 92-year-old patient with severe onychomycosis of a rare *Rhodotorula* spp. etiology, as well as an exploratory evaluation of changes in nail plate color (CIE L*a*b*) and texture based on the gray-level co-occurrence matrix (GLCM) of the nail plate, as a supplementary tool for clinical documentation.

MATERIALS AND METHODS

Procedure description

A 92-year-old patient presented to the dermatology clinic with symptoms of a fungal infection affecting the left great toenail (Fig. 1). Clinical manifestations included nail plate discoloration, onycholysis, and subungual hyperkeratosis. The etiological diagnosis was established based on routine mycological diagnostics of material obtained from the subungual space of the affected toe. Direct microscopic examination revealed yeast-like blastoconidia, and fungal culture showed growth of *Rhodotorula* spp., a rare but documented etiological agent of onychomycosis, particularly in elderly patients.

Based on the mycological examination results, systemic pulse therapy with itraconazole was initiated as follows: 4 pulses of 7 days each, at 200 mg twice daily (in total 400 mg/day), separated by 21-day drug-free intervals. Given that the patient presented to the podology clinic after therapy had already been initiated, the available medical documentation lacked history regarding concomitant systemic diseases, chronic medications, or an assessment of potential drug-drug interactions with itraconazole. However, evaluating the safety profile of the initiated pharmacotherapy in a 92-year-old patient falls outside the professional competencies of a podiatrist.

To remove hyperkeratotic debris and facilitate nail plate regrowth, concurrent podological consultations were introduced. Mechanical debridement sessions were scheduled strictly between systemic pulses to avoid interfering with peak itraconazole concentrations within the nail bed. Between the second and third cycles of systemic therapy, the patient visited the podology clinic for mechanical debridement of the diseased nail plate. During this visit, disease severity was assessed using the Onychomycosis Severity Index (OSI) [23], which accounts for the area of nail involvement, the extent of onycholysis, and discoloration. The obtained score was 16 points, corresponding to severe onychomycosis.

The mechanical debridement procedure was performed using a dry technique with a podiatry drill equipped with an integrated dust extractor, utilizing sterilized tungsten carbide burs to reduce hyperkeratosis and diamond burs to smooth the surface. As part of daily home care, the patient was instructed to apply formulations to hydrate and soften the



Fig. 1. Fungal infection affecting the nail plate of a 92-year-old male. **Source:** Own archive.

hyperkeratotic tissue of the nail bed and support the hygiene of the nail apparatus:

- PodoPharm Therapy Podoflex Mycostatic tincture for nails (INCI: Propylene Glycol, Aqua, Glycerin, Polysorbate 20, Melaleuca Alternifolia Leaf Oil, Althaea Officinalis Root Extract, Thymus Vulgaris Extract, Salvia Officinalis Leaf Extract, Citrus Aurantifolia Fruit Extract, Citrus Tangerina Fruit Extract, Rosmarinus Officinalis Leaf Extract, Calcium Sodium Borosilicate, Silver Oxide, Copper (nano), Salvia Sclarea Oil, Lavandula Angustifolia Oil, Citrus Paradisi Peel Oil, Leptospermum Scoparium Leaf Oil, Cinnamomum Zeylancium Bark Oil, Eugenia Caryophyllus Bud Oil, Phenoxyethanol, Ethylhexylglycerin, Geraniol, Limonene, Linalool, Citral, Cinnamyl Alcohol, Coumarin, Eugenol, PEG-8, Tocopherol, Ascorbyl Palmitate, Ascorbic Acid, Citric Acid),
- PodoPharm Therapy Mykobooster nail oil with hemp and CBD oil (INCI: Cannabis Sativa Seed Oil, Calophyllum Inophyllum Seed Oil, Melaleuca Alternifolia Leaf Oil, Origanum Vulgare Oil, Eugenia Caryophyllus Bud Oil, Cannabidiol, Limonene, Methyl Eugenol, Eugenol, Linalool, Isoeugenol).

Subsequent visits were scheduled at 4- to 5-week intervals and included clinical evaluation, assessment of debridement efficacy, and photographic documentation of treatment progress. A total of three podological procedures were performed during the course of systemic therapy.

The study involved the analysis of images of the nail plate of the patient with confirmed onychomycosis, obtained both before the initiation of combined dermatological-podological therapy and following its completion. To ensure a reliable comparison of image parameters, all photographs were acquired under strictly reproducible conditions, utilizing identical studio lighting, standardized camera settings, and a fixed distance from the examined surface.

Images analysis

The study analysed two photographs (before treatment initiation and after completion) of identical native resolution (pixel dimensions). The region of interest (ROI) encompassing the visible nail plate was delineated arbitrarily by manual masking for each photograph. Conversion of the segmented ROI from the RGB color space to the CIE L*a*b* model was performed using the OpenCV library, where channel values are scaled to an 8-bit representation (range 0-255). The area classified as visually altered (path_fraction) was extracted by automated segmentation using a thresholding algorithm. Subsequently, within the defined ROI, the region visually classified as discolored hyperkeratotic masses was isolated based on pixel intensity in the b* channel. The transformation from the standard RGB space to the CIE L*a*b* color model (Fig. 2) was implemented using OpenCV functions, which, for the purpose of 8-bit image processing, scale the default mathematical parameters into discrete ranges: L* from 0 to 255 (where 255 denotes maximum lightness), a* from 0 to 255, and b* from 0 to 255. Changes in these values were interpreted as mathematical metrics reflecting the visual clearing and restoration of nail plate coloration. All computational procedures were conducted in the Python analytical environment utilizing the following libraries:

- OpenCV (image processing and computer vision operations),
- NumPy (numerical matrix operations),
- scikit-image (texture feature extraction, including GLCM),
- Matplotlib (data and image visualization),
- Pandas (structured data manipulation and numerical analysis).

Texture analysis (GLCM)

To quantitatively evaluate nail-plate structure, GLCM was employed [24-26]. Four fundamental texture features were analyzed:

- Contrast - local pixel intensity variations,
- Homogeneity - the degree of local surface smoothness,
- Energy - a metric of structural uniformity,
- Correlation - spatial dependencies between neighbouring pixels.

These parameters were computed across directional angles of 0°, 45°, 90°, and 135°, and subsequently averaged to provide an objective characterization of textural alterations.

Differential analysis

Differences between parameter values before and after therapy were presented in tabular and graphical forms. A mathematical decline in GLCM homogeneity and energy values was observed, accompanied by a substantial reduction in contrast. The decrease in mathematical energy denotes a reduction in structural order and a diminished presence of large, uniform zones across the image. Biologically, this shift was interpreted as a transition from the uniformly dull, hyperkeratotic architecture of dystrophic debris to the optically nuanced, physiological microarchitecture of the regrowing nail plate, which exhibits native longitudinal striations.

RESULTS

At 22 weeks following the initiation of therapy, complete resolution of onycholysis, subungual hyperkeratosis, and distal discoloration was observed, accompanied by the outgrowth of a normally formed nail plate with no macroscopically visible dystrophic features (Fig. 3). Due to the absence of a follow-up mycological culture upon treatment completion, microbiological cure (eradication of *Rhodotorula* spp.) could not be confirmed. During the 6-month post-treatment follow-up period, no clinical signs of disease

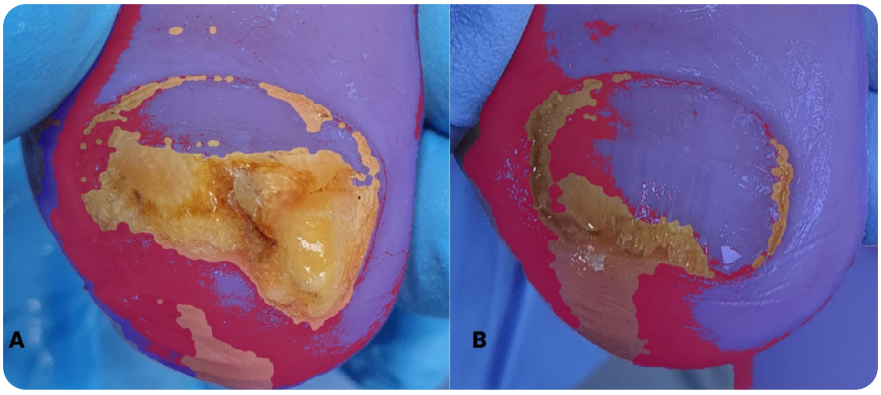


Fig. 2. Quantitative digital image analysis and color segmentation of the affected nail plate. A - Baseline (pre-treatment) presentation demonstrating severe onychomycosis characterized by pronounced hyperkeratosis, subungual debris, and extensive yellowish-brown discoloration. The colored digital overlays represent automated segmentation masks utilized for CIE L*a*b* color space transformation and calculation of the pathological area (path_fraction). B - Clinical outcome following integrated dermatological-podological therapy. A marked reduction in the pathologically altered zone is evident, exhibiting healthy nail outgrowth, a smoother surface profile, and normalization of colorimetric parameters (quantified by a decrease in the a* and b* coordinates alongside a stabilized lightness channel L*). **Source:** Own archive.



Fig. 3. Nail plate of a 92-year-old male after completion of combined dermatological and podological therapy. **Source:** Own archive.

recurrence were recorded. The quantitative image analysis served an exploratory purpose to objectify the photographic documentation (Tab. 1). Color segmentation within the CIE L*a*b* space demonstrated a reduction in the proportion of the surface area classified by the algorithm as visually altered, representing a decrease of 37.0%. This change resulted from both progressive regrowth of healthy tissue and mechanical debridement of yellowish hyperkeratotic debris. The total pixel count classified as the visible nail plate (nail_area_px) also changed. This variance is directly attributable to factors documented in the photographs: physiological outgrowth of the newly formed nail plate over the 22-week observation window and physical exposure of a broader nail surface following debridement of thick hyperkeratotic masses. Notably, given the absence of a physical millimeter reference scale and the arbitrary delineation of ROI boundaries across native-resolution images, pixel-based metrics represent relative indices. While they objectively

Tab. 1. Quantitative analysis of nail plate parameters before and after integrated dermatological-podological therapy using computer vision, CIE L*a*b* color space transformation, and GLCM texture profiling. **Source:** Own elaboration.

Parameter	Before therapy	After therapy	Change (%)	Interpretation
nail_area_px	109 379	157 993	+44.4	Increase in the number of pixels within the ROI
path_area_px	91 213	82 892	-9.1	Reduction in pixel surface area classified as visually altered
path_fraction	0.834	0.525	-37.0	Decrease in the proportion of the ROI classified as discolored
Mean L*	192.67	193.63	+0.5	Slight increase in lightness
Mean a*	133.90	128.41	-4.1	Decrease in the red component across the analyzed 8-bit scale
Mean b*	141.69	133.54	-5.8	Color evening, reduction in the yellowish discoloration of the nail plate
tex_std	34.33	36.19	+5.4	Slight increase in lightness variance, reflecting surface remodelling
tex_lap_var	917.94	276.86	-69.8	Significant reduction in surface roughness and structural irregularities
edge_density	11.66	4.88	-58.1	Reduction in edge density; smoother and more coherent surface
GLCM contrast	105.18	39.18	-62.7	Reduction in contrast, evening out of nail plate surface texture
GLCM homogeneity	0.773	0.723	-6.5	Decrease in global homogeneity resulting from the emergence of natural, nuanced striations on the regenerated plate
GLCM energy	0.600	0.425	-29.2	Decrease in structural image uniformity, reflecting tissue regeneration and new outgrowth
GLCM correlation	0.993	0.997	+0.4	Increase in correlation, indicating improved microtexture consistency

demonstrated a clear trend toward the enlargement of the exposed nail architecture, they did not constitute absolute metric measurements of anatomical surface area. Regarding GLCM texture parameters, a 62.7% decrease in contrast and a 69.8% reduction in Laplacian variance (tex_lap_var) were documented, corroborating the attenuation of chaotic surface irregularities and textural roughness. Conversely, the 29.2% decline in GLCM energy stemmed from a structural shift in the nail surface: transitioning from a uniformly dull, hyperkeratotic layer (characterized by high concentrations of repetitive pixels with uniform gray levels) to the optically diversified microarchitecture of a regenerated, native nail plate exhibiting physiological longitudinal striations.

DISCUSSION

Onychomycosis remains a significant clinical challenge, particularly in geriatric patients. In the presented case, fungi of the genus *Rhodotorula* spp. were identified as the etiological agent – opportunistic, yeast-like pathogens that are rarely isolated in nail infections [27-30]. In the literature, *Rhodotorula* species are predominantly described as commensals of the skin and mucous membranes or as contaminants of vascular catheters; therefore, documented cases of true onychomycosis caused by this microorganism remain rare [31-33]. Although systemic pulse therapy with itraconazole was initiated in accordance with guidelines, the atypical nature of the pathogen and the patient's advanced age (92 years) necessitated a more comprehensive, integrated strategy.

In severe or advanced onychomycosis, the conventional pharmacological approach, which relies solely on waiting for healthy nail regrowth, often proves insufficient. Subungual hyperkeratotic debris, which harbors fungal elements, exacerbates resistance to infection eradication. On the one hand, systemic antifungal agents delivered via the bloodstream have limited distribution within the nail bed, particularly in distal zones entrapped in isolated hyperkeratosis [34]. On the other hand, the thick layer of hyperkeratosis drastically impedes non-invasive, transungual penetration of topical formulations (such as lacquers containing amorolfine or ciclopirox), resulting in low bioavailability at the actual site of infection [35, 36]. This therapeutic challenge is further amplified in elderly individuals due to the physiologically reduced rate of nail growth, which prolongs the persistence of the infection [37].

To overcome these limitations, mechanical debridement becomes a critical clinical intervention rather than a mere aesthetic adjunct. A study by Shemer et al. [38] demonstrated that prior mechanical preparation of the nail plate can enhance the penetration of topical agents several-fold compared to an intact, untreated plate. Techniques such as mechanical debridement remove excessive hyperkeratotic layers, thereby reducing the physical distance to the nail bed. Furthermore, micro-holes and surface modifications created during the procedure serve as reservoirs for topical formulations, which significantly enhances transungual drug permeation [39, 40].

In the described patient, targeted mechanical debridement using diamond and tungsten carbide burs was incorporated between the second and third pulses of itraconazole across three visits. Although the precise extent of transungual drug penetration was not directly quantified in this study, it can be hypothesized that disrupting the dense hyperkeratotic layer potentially enhanced the absorption of the specialized supportive formulations applied.

The mechanical debridement of the nail plate was aimed at:

- reducing hyperkeratotic, dystrophic keratin masses,
- removing the hyperkeratotic mechanical barrier that restricts the normal growth and adherence of the nail bed,
- establishing more favorable conditions for the natural remodeling of the nail apparatus, as illustrated in this study using digital texture and colorimetric metrics.

It must be additionally emphasized that the concurrent use of a potent systemic agent (itraconazole), specialized podiatric procedures, and supportive topical formulations in a 92-year-old patient represents a substantial limitation for drawing definitive causal inferences. Because the therapeutic efficacy of pharmacotherapy and mechanical intervention overlap, this study could not isolate the individual contribution of each modality to the ultimate clinical resolution. The combined approach resolved visible pathological lesions within 5 months of initiating pharmacotherapy. This observation was corroborated by digital image analysis, which demonstrated a reduction in the surface area classified by the color model as altered (path_fraction), a marked decrease in structural roughness (a reduction in the tex_lap_var metric by approximately 70%), and color equalization through decreased a* and b* coordinate values. The presented clinical course suggested that mechanical debridement of the nail plate may serve as a valuable adjunct to oral itraconazole therapy; however, given the nature of a single-case report and the lack of a control group, it is impossible to determine to what extent the achieved outcome resulted from systemic medication, podiatric procedures, or the physiological outgrowth rate of the nail apparatus.

During the 6-month follow-up period after the cessation of pharmacotherapy, no macroscopic signs of disease recurrence were observed, and the patient expressed a high level of satisfaction regarding the aesthetic and functional outcomes. Nevertheless, a clear distinction must be maintained between clinical and mycological cure. The absence of a post-treatment control mycological culture represents an important methodological limitation of this

work. Restoration of a normal morphological appearance of the plate does not preclude the presence of dormant pathogen structures within the deeper layers of the nail apparatus; thus, the obtained outcome must be interpreted strictly as clinical cure.

Ultimately, this case illustrates a crucial synergy between dermatology and podiatry that remains underutilized in geriatric care. The competencies within these two disciplines are fully complementary. The dermatologist is responsible for mycological diagnostics, differential diagnosis, qualification for systemic treatment, and monitoring pharmacological safety.

The podiatrists provide safe, systematic mechanical debridement of lesions, apply targeted topical care, and routinely monitor treatment progress via standardized visual documentation.

The presented case highlights the potential benefits arising from a complementary division of responsibilities between the dermatologist (eligibility assessment, differential diagnosis, pharmacotherapy) and the podiatrists (mechanical debridement, supportive care, standardized photographic monitoring). While a single-case report does not permit the formulation of clinical guidelines or the establishment of a new standard of care, the findings may serve as an impetus for future prospective, controlled trials evaluating the efficacy of combined therapeutic regimens in the geriatric population.

CONCLUSIONS

1. The combination of systemic itraconazole pharmacotherapy and mechanical nail plate debridement led to clinical cure in a 92-year-old patient with onychomycosis caused by *Rhodotorula* spp.
2. The mechanical debridement procedures enabled the physical removal of dystrophic keratin and hyperkeratotic debris, facilitating the exposure of healthy outgrowth and resulting in high patient satisfaction with the aesthetic outcomes of the intervention.
3. Complementary collaboration between the dermatologist (responsible for mycological diagnosis and systemic pharmacotherapy) and the podiatrists (performing tissue debridement procedures) may represent a promising supportive care model, particularly in the geriatric population characterized by reduced nail growth rates.
4. The digital image analysis utilized in this study is strictly exploratory and does not represent a validated tool for evaluating treatment efficacy. However, it may serve as an auxiliary modality supporting standardized visual documentation in podiatric practice.
5. The decrease in Laplacian variance (tex_lap_var) and GLCM contrast reflected an attenuation of micro-roughness and surface irregularity following the removal of hyperkeratotic debris. This suggests the potential utility of structural descriptors for documenting macroscopic tissue changes; however, establishing their clinical validity requires further validation in independent studies with larger cohorts.

SUMMARY

This study presents the application of quantitative image analysis methods (CIE L*a*b* color space conversion, GLCM texture descriptors, edge density metrics, and Laplacian variance) to objectify the treatment outcomes of severe great toenail onychomycosis in a 92-year-old patient. A combined therapeutic regimen was implemented: pulse pharmacotherapy with itraconazole alongside three sessions of mechanical nail plate debridement. Numerical data extraction performed in the Python analytical environment demonstrated a 37% reduction in the pathological area, a 70% decrease in the surface roughness index (tex_lap_var), and normalization of colorimetric components. The data suggest that incorporating computer vision algorithms enriches subjective photographic documentation with actionable, quantitative metrics. However, this analytical modality requires rigorous procedural standardization, and its establishment as a fully recognized tool for monitoring infection treatment progress necessitates independent, extensive validation across larger clinical cohorts.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

FUNDING

This research received no external funding.

AUTHORS' CONTRIBUTIONS

JZN: Conceptualization, methodology, execution of podological procedures, image acquisition, data analysis and processing, preparation of the initial version of the manuscript (draft).

ASG: Supervision, substantive verification, literature review, editing and proofreading of the final version of the text.

ETHICS STATEMENT

Research involving human participants

Ethical committee approval was not required for this study, as the procedures performed constituted routine medical and podological care.

USE OF AI TOOLS

An artificial intelligence tool was used during the preparation of the manuscript solely for language editing.

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