

The Changing Face of Dermatophytic Infections Worldwide

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Abstract Dermatophytes evolve along with the geography and socioeconomic conditions. *Epidermophyton floccosum*, *Microsporium audouinii* and *Trichophyton schoenleinii* acted as the major pathogens of superficial fungal diseases 100 years ago, but their frequency decreased dramatically since the middle of the twentieth century and they are limited to some less-developed countries nowadays; meanwhile, frequency of *Trichophyton rubrum*, *Trichophyton interdigitale*, *Trichophyton tonsurans* and *Microsporium canis* increased gradually, and these fungi have become the major species globally. Some other dermatophytes, *i.e.*, *Trichophyton violaceum*, *Trichophyton verrucosum* and *Microsporium ferrugineum*, are mainly endemic in some parts of Africa, Asia and Europe. At present,

T. rubrum is the leading pathogen for skin and nail fungal infections, whereas *M. canis*, *T. tonsurans* and *T. violaceum* present as the predominant dermatophytes involved in tinea capitis. Population mobility, changes in human lifestyle and advents of antifungal drugs will continually drive the dermatophyte evolution in the skin microenvironment. Comprehensive observation is needed to better understand this kind of organisms and prospect the trends of their changes in future.

Keywords Dermatophytes · Epidemiology · Tinea · Evolution

Introduction

Dermatophytes are a group of filamentous fungi prone to infect keratin-rich tissues, *i.e.*, skin, nail and hair; this feature leading them to be designated as keratinolytic fungi.

The discovery of hyphae of dermatophytes in clinical materials of tinea in 1830s was the beginning of medical mycology study, which led to numerous great discoveries and rapid progress in the past century [1, 2]. Till today, it has been recognized that dermatophytoses are the most common fungal infections worldwide, affecting 20–25 % of the world population [3, 4]. An important perspective of dermatophytes is that they experienced great changes in the past 100 years [4, 5]. Factually, the evolution of dermatophytes is driven by their ecology, reproduction, host

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adaptation and pathogenicity, as well as population migration and socioeconomic status.

Dermatophytoses, infections caused by dermatophytes, are also called ringworms or tinea and are usually clinically classified according to the infectious sites: tinea pedis and tinea manuum refer to dermatophytosis of the feet and hands, and tinea cruris to lesions of inguinal, pubic, perineal and perianal areas, whereas tinea corporis affects the glabrous skin excluding the above-mentioned areas, tinea unguium (onychomycosis) the nails, tinea barbae the facial area of beard men and tinea capitis the scalp [6]. Considering the similar fungal spectrum of tinea pedis, tinea manuum, tinea barbae, tinea corporis and onychomycosis, we can summarize all these diseases into two classes. The first class comprises all infections on glabrous skin and nails, with *Trichophyton rubrum* and *Trichophyton interdigitale* as the predominant pathogens, and the second class is the hair infection, with *Microsporum canis*, *Trichophyton tonsurans* and *Trichophyton violaceum* as the major pathogens, with variations in their respective frequency with geographic locations and population [4, 5]. In this article, we give an overview of dermatophyte evolution and then introduce the most common human/animal pathogenic dermatophytes. The aim is to get a comprehensive understanding of these organisms and prospect the trends of their changes in future.

History and Taxonomy Evolution of Dermatophytes

The first dermatophytic infection case, kerion, was recorded around 30 A.D in Roman and described as a suppurative infection on scalp, which suggested this organism has lived with human beings for thousands of years [1, 7]. However, due to lack of effective tools of observation, this kind of damage was named as tinea or ringworm because of its clinical appearance, but it was not related to microorganism. The etiological agent of tinea capitis, *Trichophyton schoenleinii*, was discovered around 1830s, in crust of favus by Robert Remark, Johann Lucas Schoenlein and David Gruby, which was regarded as the start of medical mycology [1, 7, 8]. In 1886, Paul Grawitz and Emile Duclaux isolated some dermatophytes in pure cultures independently [1, 8]. Henceforth, *Microsporum audouinii*, *Trichophyton mentagrophytes*, *T. tonsurans* and *Epidermophyton*

floccosum were successively reported on either the basis of the appearance of clinical materials or described under the microscope [1, 2, 7]. At the beginning of the twentieth century, Raymond Sabouraud took advantage of the newly developed culture medium for isolation, identification and maintenance of dermatophytes, and established the taxonomic criteria for these fungi. He integrated the mycological and clinical aspects into a comprehensive concept, and classified the dermatophytes into four genera, *Achorion*, *Microsporum*, *Trichophyton* and *Epidermophyton* [1, 9, 11]. Due to his great contribution, Sabouraud was regarded as “the one man who truly revolutionized our concepts of dermatophytes and who immeasurably contributed to the development of medical mycology” [7]. Dermatophytes were described and categorized by their vegetative structure, their conidia and their anamorph/teleomorph state. The genus name *Achorion* was deleted in 1934 by Emmons, Sabouraud’s student, and the other three genera reserved till today [10, 11]. Due to the unstable characteristics and too much unrelated factors involved, a new genus/species was very easily reported; in 1935, Dodge introduced 118 species of dermatophytes in his book *Medical Mycology* which reflected at some extent the confusion of dermatophyte denomination at the first half of the twentieth century [1, 7]. In addition, some authentic strains are now missing, and precise taxonomy of the first reported species is not available today.

Since 1980s, molecular methods made taxonomy of organisms much more plausible and clear. Yvonne Graser, Koichi Makimura, Sybren de Hoog and others dedicated great contribution to this work, and in 2011 the Amsterdam Declaration on Fungal Nomenclature was adopted promoting the idea of “one fungus one name” to clarify the nomenclature of fungi though this new system still keeps some limits [12–14]. Many molecular methods were applied for strain or species identification and taxonomy of dermatophytes, e.g., random amplification of polymorphic DNA (RAPD), PCR fingerprinting, amplified fragment length polymorphism (AFLP), microsatellite markers, single-strand conformation polymorphism (SSCP) and sequencing of one or multiple loci [13]. Factually, taxonomy of these fungi will change inevitably with the development of scientific techniques and keeps dynamic at present [14]. In the newly taxonomic tree, Sybren de Hoog et al. (unpublished data) classifies dermatophytes into six clades

based on multilocus genetic analysis, *Trichophyton*, *Epidermophyton*, *Nannizzia*, *Microsporium*, *Lophophyton* and *Arthroderma*.

Evolution of Dermatophytes Before 1980s

The spectrum of dermatophytes has experienced great evolution in the first half of the twentieth century and changed by geography and population. From 1930 to 1950, *M. audouinii* and *T. schoenleinii* were the predominant agents of tinea capitis in British islands, Northern and Western Europe and America, while *T. mentagrophytes* was the main agent for tinea pedis and tinea corporis [15]. It is worth noting that frequency of tinea pedis increased dramatically along with the global migration after the World War II. In contrast, frequency of tinea capitis has declined greatly due to the advent of griseofulvin in the mid of 1950s and improved hygiene [4, 5]. *Trichophyton rubrum* was very rare in Europe before 1940s [15].

Since 1950s, the frequency of *M. audouinii* and *T. schoenleinii* in British islands, North and Western Europe declined along with an increased frequency of *M. canis*, *T. mentagrophytes* and *T. verrucosum*, the latter became the most important agent isolated from scalp. In North America, *T. tonsurans* took the place of *M. audouinii* as the most common agent for tinea capitis followed by *M. canis* [15–17], and *T. rubrum* expanded, together with *T. mentagrophytes* and *E. floccosum*, as a common cause of superficial fungal disease worldwide, except infections on scalp [15, 18]. Etiology of dermatophytosis in Australia was much similar to that of North America except that *M. audouinii* was rarely reported in Australia. It is thought that its spread was prevented by *M. canis* [15, 19].

Differences in the dermatophyte spectrum for tinea capitis were observed in Mediterranean countries and Eastern Europe, where *M. canis*, *T. mentagrophytes*, *T. violaceum* and *T. schoenleinii* acted as the major agents, changing with areas [15, 16, 18].

Few original reports could be reviewed before 1960s for Africa, Asia and Middle East. Between 1960s and 1970s, *E. floccosum*, *M. ferrugineum*, *T. violaceum* and *T. schoenleinii* were highly popular in these areas as the main causes of scalp ringworm yet their respective frequency varied by regions [15, 20, 21].

Epidemiology of Dermatophytoses Since 1980s

In recent 30 years, the spectrum of dermatophytes showed slower evolution though some changes keep happening. Table 1 lists some of the large studies reported since 1980.

Trichophyton rubrum almost presents as the predominant species for tinea on skin and nails worldwide. *Trichophyton mentagrophytes* ranks the second and even shows as the most common agent in some countries like Venezuela, Iran and Croatia [22–24]. *Epidermophyton floccosum*, *T. tonsurans*, *T. violaceum*, *M. canis*, *M. audouinii* and *M. ferrugineum* are also responsible for some proportions of tinea corporis and onychomycosis in some areas of the world. *Epidermophyton floccosum*, which disappeared for many areas, accounted for 16–40 % of cases in Tehran, Iran [23, 25, 26], whereas *M. audouinii*, *T. soudanense* and *T. schoenleinii* are still popular in Africa [27–29].

The agents of tinea capitis showed much obvious geographic changes. *Microsporium canis* is the leading agent of tinea capitis in most parts of Europe and Asia. *Trichophyton tonsurans* presents as the predominant cause of tinea capitis in North/South America and the United Kingdom [15, 30, 31], and *T. violaceum*, *T. schoenleinii*, *M. ferrugineum* and *M. audouinii* are still epidemic in Africa, Eastern Europe and Asia [15, 32–36].

Population mobility, the advent of new antifungal agents, popularization of leather shoes and sneakers, improvement of human hygiene are responsible for this shift in the dermatophyte spectrum [4, 37]. Ping et al. [32] reported a big shift from anthropophiles to zoophiles in the past 60 years in China.

Dermatophytes, Related Diseases and History Evolution

Concerning their natural habitat, host preference and transmission route, dermatophytes can be divided into anthropophilic, zoophilic and geophilic species. Generally speaking, anthropophilic dermatophytes which are characterized by human to human transmission are geographically limited except for *T. rubrum*, which is most frequently isolated in developing countries and usually associated with low socioeconomic status [4, 5]. By contrast, zoophilic species which are related

Table 1 Epidemiology of dermatophytes worldwide since 1980s

Author and reference	Area	Period	Diseases [#]	Most frequently isolated species* (%)						
Asia										
Wu et al. [41]	China	1986	N (8004)	TR 57	TM 24	TV 8				
		1996	N (10835)	TR 73	TM 22	MC 4				
		2006	N (13209)	TR 75	TM 18	MC 8				
Cai et al. [42]	Guangzhou, South China	2004–2014	S&N (479) TC (109)	TR 81	TM 15	MC 3				
Shahindokht et al. [25]	Tehran, Iran	2000–2005	S&N (4321)	TR 27	TM 21	EF 34	TT 10	Tver 7		
				TV 32	TT 37	MC 12	TS 12			
Rezaei-Matehkolaei et al. [26]	Tehran, Iran	2008–2010	S&N (762) TC (15)	TR 35	TM 41	EF 16				
				MC 33	TT 20	TM 20	TS 13			
Rezaei-Matehkolaei et al. [23]	Khuzestan, Iran	2013–2014	S&N (911) TC (120)	TM 56	EF 40	MC 2				
				TM 83	TV 2	MC 13				
Abanmi et al. [61]	Saudi Arabia	2003–2005	S&N (45)	TR 23	MC 35	TT 12				
			TC (26)	TM 58	MC 29	TR 7				
Europe										
Andrew et al. [31]	British Isles	1980	N	TR 62	TM 18	TT 0.3				
		1990	N	TR 66	TM 22	TT 1				
		2000	N	TR 70	TM 22	TT 5				
Faure-Cognet et al. [62]	Grenoble, France	2001–2011	S&N (1285)	TR 82	TM 3	MC 1				
			TC (73)	TT 24	TM 10	TV 1	Tver 1			
Monod et al. [63]	Lausanne, Switzerland	1993–2000	S&N (3806) TC (387)	TR 68	TM 26	MC 3				
				MC 26	TV 16	TM 14				
Nowicki [64]	Gdansk area, Poland	1984–1995	N (969)	TR 16	TM 42	MC 28	EF 10			
Budak et al. [65]	Krakow, Poland	1995–2000	S&N (1559)	TR 55	TM 38	EF 2	MC 2			
			TC (39)	TR 39	TM 26	MC 15	MG 11			
Saunte et al. [66]	Denmark	1993	S&N (3603)	TR 66	TM 25	MC 5	EF 3			
			TC (206)	MC 84	TV 11	TM 2				
		2003	S&N (5329) TC (185)	TR 80	TM 15	MC 2	EF 1			
				MC 57	TV 35	Maud 3				
Babic-Erceg [67]	Split, Croatia	1996–2002	N (858)	TR 22	TM 25	TT 4				
Paola et al. [68]	Zagreb, Croatia	1999–2008	S&N (9304)	TR 12	TM 68	MC 17				
			TC (1767)	MC 92	TM 6	MG 1				
Tsoumani et al. [69]	Southwestern Greece	1991–1999	S&N (897)	TR 40	MC 56	TM 2				
			TC (63)	MC 78	TM 19					
		2000–2008	S&N (261) TC (28)	TR 47	MC 43	TM 10				
				MC 75	TR 14	TM 11				
Loranne et al. [70]	Malta	1995–1999	S&N (293)	TR 39	TM 25	MC 19	MG 9			
			TC (60)	MC 83	Tsou 7	TM 3				
America										
Lopez-Martinez et al. [70]	Mexico	1996–2006	S&N (1789) TC(83)	TR 83	TM 6	TT 5	MC 4			
				TC 70	MC 25					
Sinski et al. [71–73]	USA	1979–1981	N (6502)	TR 54	TTR 28	TM 9	EF 5	MC 4		
		1982–1984	N (6220)	TR 47	TT 33	TM 10	EF 4	MC 5		
		1985–1987	N (14696)	TR 55	TT 31	TM 6	EF 2	MC 4		

Table 1 continued

Author and reference	Area	Period	Diseases [#]	Most frequently isolated species* (%)				
Weitzman et al. [74]	USA	1993–1995	N (26815)	TT 45	TR 41	TM 9	MC 3	Ef 1
Diniz et al. [75]	Mato Grosso, Brazil	2009	N	TR 33	TT13	MG 8	Tver 11	
Arenas et al. [76]	Dominican Republic	2010	TC (118)	TT 61	Maud 24	MC 12		
Nilton et al. [77]	São Paulo, Brazil	2005–2011	N (2626)	TR 96	TM 2	MG 1		
Africa								
Oke et al. [27]	Ile-Ife, Nigeria	2011	S&N (18) TC (96)	EF 44 Maud 46	TR 50 TR 26	TM 6 TM 18	TS 10	
Ayanbimpe et al. [50]	Central Nigeria	2004	TC (245)	Tsou 31 TT 7	Mfer 8 MC 7	Maud 8	Tm 7	
Neji et al. [29]	Sfax, Tunisia	1998–2007	S&N (12873) TC (1350)	TR 87 TV 58	TM 8 MC 30	TV 3 TM 3		

TR, *Trichophyton rubrum*; TM, *Trichophyton mentagrophytes* (As *Trichophyton interdigitale* and *Arthroderma benhamiae* were not separated from *Trichophyton mentagrophytes* in most publications, we designated all these three species as *T. mentagrophytes* in our analysis); TV, *Trichophyton violaceum*; Tver, *Trichophyton verrucosum*; TS, *Trichophyton schoenleinii*; Tsou, *Trichophyton soudanense*; MC, *Microsporum canis*; Maud, *Microsporum audouinii*; Mfer, *Microsporum ferrugineum*; EF, *Epidermophyton floccosum*

[#] S&N, infections of skin and nail; TC, tinea capitis; and N, diseases not separately analyzed. Numbers in *brackets* indicate the total number of dermatophyte strains isolated

* Numbers (%) indicate the species distribution among all dermatophyte strains identified from the clinical samples analyzed; only the most common species are listed

to pet feeding and farming work increase dramatically nowadays and show a global distribution, especially in Europe and Asia [5]. *Microsporum canis* and *T. mentagrophytes* are the major pathogenic species belonging to this category. Geophilic dermatophytes grow in soil and sporadically infect humans, with *Microsporum gypseum* as the most common pathogen for human in this group [4].

Numerous reports about the epidemiology of dermatophytoses have been published in recent years (Table 1). Reports from Europe are more numerous than those from Asia, Africa, America and Australia. However, we can speculate that superficial fungal infections are more prevalent in Africa and Asia due to the ecological diversity in tropical/subtropical areas and low socioeconomic status. However, the lack of research groups about dermatophytes, professional technicians and limit of laboratory diagnosis are the

major limitations for epidemiological research in most developing countries.

Trichophyton rubrum *Trichophyton rubrum* is the leading etiological agent of most superficial infections on skin and nails. Interestingly, this species is relatively new to human beings compared to the other main dermatophytes [38]. It was described by Castellani in 1910 and named as *Epidermophyton rubrum* firstly and then changed to *T. rubrum* by Sabouraud in 1911 [7, 10]. The first clinical case due to this organism, corresponding to tinea pedis, was reported in 1927, in the USA [7]. Microsatellite analysis suggested that it originated from Africa, followed by the emergence of a new genotype in Asia with subsequent spread of this genotype over Europe and the United States by population expansion and immigration around the Second World War [39, 40]. It has since become the most common etiologic agent of

tinea corporis, tinea pedis and tinea manuum, tinea cruris, tinea unguium (onychomycosis) and subcutaneous dermatophytosis (Majocchi granuloma), representing about 50–80 % of these infections [4, 41, 42]. *Trichophyton rubrum* seldom infects hair due to its incompetence of invading into follicle and hair.

A broad spectrum of species close to *T. rubrum* was nominated in the history, including *Trichophyton megninii*, *Trichophyton balcanicum*, *Trichophyton rodhainii*, *Trichophyton kuryangei*, *Trichophyton circonvolutum*, *Trichophyton fischeri*, *Trichophyton fluviomuniense*, *Trichophyton glabrum*, *Trichophyton gourvillii*, *Trichophyton kanei*, *Trichophyton pedis*, *Trichophyton raubitschekii*, *Trichophyton soudanense*, *Trichophyton violaceum* and *Trichophyton yaoundei*, which revealed high sequence homology by molecular analysis, and are now summarized into a generic term, *Trichophyton rubrum* complex [38, 40]. This complex can be divided into two groups according to Graser et al. [38, 39]: *Trichophyton rubrum* clade (representative member is *Trichophyton rubrum* Castellani) and *Trichophyton violaceum* clade (representative member is *Trichophyton violaceum*). The former group is related to the infections of skin and nails, whereas the latter is recovered from scalp infections with endothrix-type hair invasion [38]. *Trichophyton rubrum* sibling species are anthropophilic, transmitting from human to human by direct or indirect contact, and usually induce chronic, mild inflammation. The classical species, *T. rubrum*, has a global distribution, without preference of gender, race and age [43]. However, it prefers warm and humid climates and more easily infects outdoor and hard working population, which explains why in most epidemiological reports males exceed females and more cases are reported from tropical and subtropical countries [6].

Trichophyton mentagrophytes. *Trichophyton mentagrophytes* was discovered by David Gruby in tinea barbae, and named later as *Microsporium mentagrophytes* by Robin (1853), but then transferred to the *Trichophyton* genus by Blanchard (1896) [7]. Gruby [7] also recognized its ectothrix forms of hair invasion. *Trichophyton mentagrophytes* presents a global distribution with no bias of climate, race and regions. After *T. rubrum*, *T. mentagrophytes/T. interdigitale* is the second causative agent of tinea corporis and onychomycosis in most countries. However, in southwestern Iran and Venezuela, the frequency of *T. mentagrophytes/T. interdigitale* is significantly higher, these species being

more common than *T. rubrum*, acting as the leading causative agents of superficial fungal infections [22, 23]. Additionally, *T. mentagrophytes* can invade hair and follicles, causing black dot and kerion type of tinea capitis. It is also the major pathogen for tinea faciei and tinea barbae, accounting for 70 % of cases in some reports [23, 44].

Trichophyton mentagrophytes sibling species form the most polymorphic group within dermatophytes, which comprises at least four clades, i.e., *T. interdigitale* (with no known teleomorph), *T. mentagrophytes* (with the teleomorph *Arthroderma vanbreuseghemii*), *Trichophyton simii* (with the teleomorph *Arthroderma simii*), *Trichophyton erinacei* (with no known teleomorph) and *Arthroderma benhamiae*. Among these species, *T. interdigitale* is the only one anthropophilic, the others being zoophilic or geophilic [45, 46]. Due to their variable pleomorph and limited resolution capability, these siblings make confusion to mycologist and clinical doctors and are usually summarized into the *T. mentagrophytes* complex in practice. Multilocus genetic analysis might clarify this dilemma in near future and bring us clear taxonomy of dermatophytes.

Microsporium canis. *Microsporium canis* was reported in 1902 by Bodin as *Microsporium lanosum* and its name was changed to *Microsporium canis* by Sabouraud in 1908 [7, 47]. It is a zoophilic species with a worldwide distribution. A wide variety of lower animals and cats and dogs are the main reservoir. The etiology of tinea capitis experienced great evolution since the 1950s from *T. schoenleinii* and *M. audouinii* to *M. canis* and *T. tonsurans* [5, 48]. Nowadays, *M. canis* is the predominant agent for tinea capitis, highly widespread in Asia, Mediterranean countries and Central Europe [5, 49]. In Chinese megacities, i.e., Beijing, Guangzhou and Chongqing, *M. canis* accounts for 80 % of all cases of tinea capitis [32]. While, the epidemiology of tinea capitis in Africa and some less-developed regions in Asia, i.e., Iran and northern west China, appears to sustain an old transmission route of human to human mode, with the spread of a broad spectrum of anthropophilic species [32, 50]. *Microsporium audouinii*, *T. violaceum*, *M. ferrugineum* and *T. soudanense* remain endemic as the major agents of tinea capitis, notably in Kenya, Malawi, Ethiopia and Nigeria [50, 51]. Along with the immigrations, reappearance of *M. audouinii* and *T. violaceum* has been reported in Europe recently, and they have been confirmed by molecular fingerprinting to come from

African countries and spread to some European countries by human contact (see below) [52].

Microsporium audouinii. *Microsporium audouinii* was firstly discovered by David Gruby in 1843 in clinical samples and named in 1902 [7]. It is commonly regarded as an anthropophilic dermatophyte. However, rare isolation came from animal and soil indeed [53, 54]. This fungus had a worldwide distribution, highly epidemic in the nineteenth century, generally found in prepubescent children, causing tinea corporis and tinea capitis. Due to its high sensitivity to griseofulvin, it was almost eliminated after 1950s. Currently it is only isolated in Africa and some parts of Europe and Asia. In some African countries, i.e., Nigeria [27] and countries in West Africa [28], it even acts as the leading organism of superficial fungal diseases. However, reappearance of *M. audouinii* was reported in Belgium and Germany recently [52, 55], as well as in the Zurich area of Switzerland [44], as a result of Africa immigration into Europe (see above introduction of *Microsporium canis*).

Trichophyton violaceum. *Trichophyton violaceum* is another important species within the *T. rubrum* complex. Conversely to *T. rubrum*, it is geographically limited and mainly causes tinea capitis. This organism also originated from Africa and then became popular in Europe and Asia at the late nineteenth and the early twentieth century. It became an important agent of tinea capitis in Africa, Europe and Asia, as well as *T. schoenleinii* and *M. ferrugineum*. In China, *T. violaceum* accounted for 28.8 % of cases of tinea capitis, while *T. schoenleinii* and *M. ferrugineum* were the causal agents in 44.7 and 20.7 % of the cases during a 30-year period, from 1956 to 1985 [33]. Since then, its frequency decreased rapidly and it was replaced by *M. canis* in most of its once popular areas [32, 33]. Nowadays, it remains in some African countries, Eastern Europe, Middle East and South and West China. Nevertheless, an increasing occurrence of *T. violaceum* infections, as the predominant pathogen for tinea capitis, was reported in Milan (Italy) [34]. Foreigners from Africa are usually regarded as the infectious source. However, excluding Africa and Europe, amounts of cases have been reported in Middle East, Northwest and Southern China [25, 32, 33]. In Southern cities of China, Nanchang and Shanghai, *T. violaceum* ranks the first and the second pathogen for tinea capitis, respectively

[32, 35]. In addition to tinea capitis, *T. violaceum* can infect skin and nails, causing tinea corporis, tinea pedis, tinea manuum, tinea cruris and onychomycosis.

Trichophyton tonsurans. *Trichophyton tonsurans* was firstly described by David Gruby as causing an endothrix form of hair invasion [7]. However, it is the Swedish scientist, Malmsten who named it in 1845 [10]. This anthropophilic dermatophyte has a worldwide distribution, but with frequency variations from continent to continent nowadays. This organism is mainly popular in North America (Canada, the USA), the United Kingdom and Western Europe, infecting hair and causing black dot tinea capitis, as well as infecting skin causing tinea corporis. Additionally, *T. tonsurans* may be recovered from the scalp of asymptomatic carriers and is the etiological agent for small outbreaks of tinea corporis and tinea capitis among kindergartens, health centers, family members and sports clubs [56–58].

Conclusions

The fungal biota of superficial infections varies not only geographically but also historically. In the past 100 years, dermatophytes experience great evolution worldwide. Those which were highly popular among human beings around 1930 and 1940s, e.g., *T. schoenleinii*, *M. audouinii*, *E. floccosum* and *M. ferrugineum*, are being disappearing from most countries and limited to some less-developed countries. *Trichophyton tonsurans* shows an upward trend in America and Europe, but its frequency still remains low in developing countries [15, 30, 33]. Zoophilic dermatophytes, mainly *M. canis*, gradually increased since the twentieth century, mainly because of the petting popularization [33]. *Microsporium canis* is the most common dermatophyte isolated from animals, followed by *T. mentagrophytes*, *M. gypseum* and *T. verrucosum* [59, 60].

In addition, a new feature of superficial fungal infections nowadays should be mentioned, that is the gradually increased frequency of yeast and yeast-like skin infections in tropical and subtropical countries, while dermatophytoses decrease continually, together with the increased frequency of hospital-acquired infections along with the increased number of immunocompromised patients since the late 1900s [41].

Changes in life style will inevitably promote a shift in the spectrum of fungal biota responsible for skin infections. It can be speculated that, due to the improvement of hygiene, generalization of animals quarantine and modern lifestyle, these organisms will shift from zoophilic (*M. canis* and *T. mentagrophytes*) to anthropophilic species (*T. rubrum*, *T. tonsurans* and *T. violaceum*), which transmit in a hidden way and cause mild inflammation. Many attempts have been made to eliminate dermatophytes and factually achieved great contributions indeed [5, 32, 33]. Interdisciplinary cooperations are needed to control this kind of disease and achieve maximum results, including efforts from public health organization, accurate diagnosis from clinical works, governmental intervention and social surveillance.

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