Dermatophytes: Keratin Eaters

Aruna G.L.1 and Ramalingappa B2

1Postgraduate Department of Microbiology, Maharani’s Science Collage for Women, Mysore - 570 005, Karnataka, India.
2Department of Studies and Research in Microbiology, Davangere University, Davangere, Karnataka, India.

Corresponding author Email: microarunagl@gmail.com

(Submitted on June 14, 2023; Accepted on March 11, 2024)

ABSTRACT

Dermatophytes are a group of closely related keratinophilic fungi belonging to the anamorphic genera Trichophyton, Microsporum and Epidermophyton. They have the capacity to invade keratinized tissue such as skin, hair, and nails of humans and animals to produce a superficial mycotic infection called dermatophytosis. In one of the survey conducted by World Health Organization (WHO), it has been reported that about 25% people worldwide have cutaneous infections. People of all ages are affected by the dermatophytosis. Migration, climatic factors, growth in tourism, changes in socioeconomic conditions, overcrowding, healthcare, environmental hygiene, culture and individual characteristics may influence the epidemiology of dermatophytoses. There are different types of dermatophytosis and have been named according to the anatomic locations involved. The main aim of this paper is to review the etiology, prevalence, and clinical presentation, the latest knowledge on pathogenesis of dermatomycosis. This article mainly focuses on recent published work on different aspects of dermatophytes.

Keywords: Dermatophytosis, Keratinophilic, Anthropophilic, Dermatophytes, Serology, Onychomycosis, Ringworm, Griseofulvin.

INTRODUCTION

A group of closely related keratinophilic fungi are called dermatophytes. They can invade keratinized tissues of humans and animals such as stratum corneum of skin, hair and nails causing superficial infection called dermatophytosis (Weitzman and Summerbell, 1995; Garg et al., 2009). These organisms are particularly well adapted to infect this location even though they are not part of the normal human skin flora, because they have the ability to use keratin as a source of nutrients by producing extracellular enzymes named keratinases, unlike most other fungal pathogens (Wagner and Sohnle, 1995). Based on the formation and morphology of their conidia dermatophytes are classified into three genera namely Trichophyton, Microsporum and Epidermophyton, (Simpanya, 2000; Madhavi et al., 2011; Cortez et al., 2012). Each of which includes several recognized species (Roque et al., 2006). Nowadays 41 species of dermatophytes were identified (Gharachorlo et al., 2011). These fungi are distributed worldwide with various degrees (Coelho et al., 2011; Woodfolk, 2005; Bokhari, 2009). These fungi are both keratinophilic and keratolytic (Blanco and Garcia, 2008; Shrivastav et al., 2013).

CLASSIFICATION OF DERMATOPHYTES

Dermatophytes are classified according to the genera, the ecology and patterns of infection (Palacio et al., 2000).

ECOLOGICAL CLASSIFICATION

Dermatophyte species are traditionally classified into three groups based on the ecological niche in which they reside. These include geophilic species that live in soil, zoophilic species that are associated with animals, and anthropophilic species that associated with humans (Peres et al., 2010; Ndako et al., 2012; Summerbell, 2000; Abdo et al., 2011). Some of these dermatophytes have developed host specificity probably during their evolution from their natural habitat in the soil. The difference in host specificity is because of the differences in keratin of the hosts (Simpanya, 2000).

Anthropophiles

Anthropophilic species usually infect humans but they may also infect animals. Infection transmits from man to man (Abdo et al., 2011). They account for over 70% of infections in humans and can lead to a persistent illness (Peres et al., 2010; Achterman and White, 2012). These fungi typically produce superficial dermatomycoses characterized by relatively low inflammatory activity. According to Havlickova et al. (2002), household dust can serve as a reservoir for antropophilic dermatophytes by retaining spores of dermatophytes for years (Havlickova et al., 2002).

Zoophiles

Zoophilic species infect animals and transmission from animals to humans can occur (Simpanya, 2000;
Weitzman and Summerbell, 1995). They are pathogens with only one animal host and grow as saprophytes on animal materials. Human beings acquire the infection from infected animals (Lakshmipathy and Kannabiran, 2010). They have a high affinity to the hairy head of a child. About 30% of human dermatophytes are caused by zoophilic organisms, which frequently cause acute inflammation and have a self-healing characteristic (Achterman and White, 2012). They are associated to skin diseases that are extremely inflammatory and maybe highly infectious (Havlíčkova et al., 2002).

**Geophiles**

Geophilic species inhabit soil and infect both humans and animals. Certain species are maintained and spread by fomites (Simpanya, 2000). They are often saprophytic and obtain nutrients from keratinous substrates (Lakshmipathy and Kannabiran, 2010). They are thought to have been ancestral to the pathogenic dermatophytes, pre adapted to cutaneous pathogenesis by their ability to use keratin and their consequent close association with animals living in hair and feather-lined nests in contact with soil (Weitzman and Summerbell, 1995). These fungi only sporadically infect humans (Havlíčkova et al., 2002).

**ETIOLOGICAL AGENT**

The dermatophytes consist of three anamorphic (asexual or imperfect) genera, *Epidermophyton*, *Microsporum* and *Trichophyton*. They belong to the class hyphomycetes of the Deuteromycota (Fungi Imperfecti) (Weitzman and Summerbell, 1995; Stojanov et al., 2011).

**Trichophyton**

The genus *Trichophyton* consists of 24 species, the most frequent species include, *T. mentagrophytes*, *T. rubrum*, *T. verrucosum* and *T. violaceum*. On agar media, they form powdery, velvety or waxy colonies. *Trichophyton* species can be identified by characteristic reverse side pigmentation. For instance, the pigmentation on the reverse side of *Trichophyton rubrum* is wine red colour. Microconidia are more predominant than macroconidia (Weitzman and Summerbell, 1995; Stojanov et al., 2011). Microconidia, may be globose, pyriform or clavate, or sessile or stalked, and are formed singly along the sides of the hyphae or in grape-like clusters. They are 2-3μm in size (Simpanya, 2000). The macroconidia are thin walled with smooth surface and cigar-shaped or pencil shaped; they may become cylindrical, or resemble a long wedge, having 1 to 12 septae. They appear alone or in the group. They are 8–86 μm x 4–14 μm in size. Some species rarely produce macroconidia (Lakshmipathy and Kannabiran, 2010; Stojanov et al., 2011). The type species is *T. tonsurans* (Weitzman and Summerbell, 1995; Simpanya, 2000).

**Microsporum**

The genus *Microsporum* consists of 16 species. The *Microsporum* species forms either white velvety or powdery colonies with yellowish brown pigmentation at the center and yellowish to brown pigmentation on the reverse of the colonies. The colonies possess radial ridges. *Microsporum* species produces both macro and microconidia (Lakshmipathy and Kannabiran, 2010; Mihali et al., 2012), but the predominant conidia are macroconidia. Macroconidia are less abundant. The macroconidia are multi septate (1 to 15 septa) with a thin or thick echinulate cell wall and are spindle shaped. Originally, the macroconidia were described by Emmons as spindle shaped or fusiform, obovate (egg shaped) in *Microsporum namum* and cylindrofusiform in *Microsporum vanbreuseghemii* and may be numerous or scarce. However, the essential distinguishing feature of this genus is the presence of echinulations on macroconidial cell wall. The thickness of the cell wall and shape varies depending on the species. They range in size from 6 to 160 by 6 to 25 mm (Stojanov et al., 2011). They can be stocky, with stalk or sphenoid appearance, usually individually situated along hyphae. Microconidia are pyriform, about 2-3μm in size. They are sessile or stalked. They are clavate and usually arranged singly along the hyphae or in racemes as in *Microsporum racemosum*, a rare pathogen (Weitzman and Summerbell, 1995). The type species is *M. audouinii* (Simpanya, 2000). Rarely some species produce neither micro nor macroconidia. They do not have any special nutritional requirements (Lakshmipathy and Kannabiran, 2010).

**Epidermophyton**

The genus *Epidermophyton* consists of only 2 species among them the pathogenic one is *E. floccosum* (Lakshmipathy and Kannabiran, 2010; Stojanov et al., 2011).

The colonies are slow-growing, the fresh colonies are white and cottony, old culture is powdery and unique brownish yellow in color (Lakshmipathy and Kannabiran, 2010). This genus does not produce microconidia. Macroconidia are abundant and produced singly or in clusters. They are large, multicellular with one to nine septa, club-shaped and thin walled with smooth surface (Weitzman and Summerbell, 1995; Simpanya, 2000; Stojanov et al., 2011). They are 20 to 60 by 4 to 13 mm in size (Weitzman and Summerbell, 1995).
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Figure 1: Dermatophyte cultures on SDA medium. a, *Trichophyton rubrum* culture on SDA medium, a(i) Obverse, a(ii) Reverse; b, *Microsporum canis* culture on SDA medium, b(i) Obverse, b(ii) Reverse; c, *Epidermophyton floccosum* culture on SDA medium, c(i) Obverse, c(ii) Reverse.

Figure 2: a, Dermatophyte Test Medium (DTM); b, *Trichophyton rubrum* culture on DTM; c, *Microsporum canis* culture on DTM; d, *Epidermophyton floccosum* culture on DTM.

Figure 3: Microscopic view of lacto phenol cotton blue stain wet mount. A, *Microsporum canis* macroconidia under 100X; b, *Epidermophyton floccosum* macroconidia under 40X; c, *Trichophyton rubrum* microconidia under 40X.

EPIDEMIOLOGY AND ECOLOGY

Epidemiology plays an important role in control of infection and public health issues ((Weitzman and Summerbell, 1995). It has been reported that, the frequency of dermatophytosis has changed over the last few years. Several workers reported that *Trichophyton rubrum* is predominantly prevalent species throughout the world (Sharma and Sharma , 2012) . Several workers reported on dermatophytosis from different parts of the country, but there are only few workers reported on the involvement of non dermatophytic fungi and yeast like fungi in superficial mycoses (Hitendra et al., 2012).

The epidemiology of dermatophyoses is influenced by migration, climatic factors, growth in tourism, changes in socioeconomic conditions, overcrowding, healthcare, environmental hygiene, culture and individual characteristics (Ndako et al., 2012; Dehghan et al., 2009; Ameen, 2010). Generally, dermatophytes are cosmopolitan in distribution, that is, they occur in different regions of the world with variations in the frequency of particular species (Peres et al., 2010; Palacio et al., 2000; Dehghan et al., 2009; Seebacher et al., 2002; Segal and Frenkel, 2015). It occurs very commonly in tropical and subtropical countries (Mathur et al., 2012).

According to the World Health Organization (WHO), 25% of the world population is affected by dermatophytes. It is estimated that from 30 to 70% of adults are the carriers of these pathogens and that the incidence of the disease increases with age (Seebacher et al., 2002). *T. rubrum* is the most frequent in clinical cases of tinea pedis, tinea unguium, tinea corporis and tinea cruris (Havlickova et al., 2002). The symptoms and the causative organism of dermatophytosis vary with geographic region, socioeconomic conditions and habits. In developed countries contributing factors to the development of dermatomycoses include animals, increased use of public sports facilities (especially swimming pools), wearing impenetratable training shoes, the increasing incidence of diabetes mellitus.
and vascular disease and an ageing population, foot trauma and cigarette smoking.

The dermatophytes are being imported and disseminated by booming mass tourism, international sports activities and increasing migration (Havlickova et al., 2002). The mode of infection may by direct contact or indirect contact. Direct contact with patients and infected pet animals. Swimming pools, seabeaches etc., which could serve as reservoir of skin debris of infected individuals, which could transmit the disease indirectly (Segal and Frenkel, 2015).

In recent decade, the prevalence of dermatophytosis has significantly decreased in many developed nations of the world due to improved social, economic, health care and hygiene practice factors in the former (Ndako et al., 2012).

BIOCHEMISTRY OF PATHOGENESIS

The dermatophytes enter into the host body through injured skin, scars and burns. Either arthrospores or conidia are source of infection. (Lakshmipathy and Kannabiran, 2010). The mannann glycoproteins in the cell wall of the dermatophytes helps in the attachment to the keratin containing epithelial tissue of the host. Although the pathophysiological mechanisms of dermatophytes are poorly studied, it is known that, similar to other filamentous fungi, conidial germination proceeds in three stages: activation, isotropic growth, and polarity growth. Ultrastructure observation of human skin sections during dermatophyte infection revealed that Trichophyton mentagrophytes spores attach to the stratum corneum after 12 hours. Lemsaddek et al. (2010) reported that the elongation of the germ tube promotes the invasion and release of several lipolytic and proteolytic exoenzymes, which enter the cornified cells (Lemsaddek et al., 2010). According to numerous reports the pathogenicity of dermatophytes is associated with their synthesis of proteinases, which allow them to feed on keratin and other proteinaceous substrates found in the stratum corneum, nails, and hair (Venkatesan et al., 2002; Samdani, 2005). Numerous proteases have previously been identified from various dermatophyte species and displayed keratinolysis, elastolysis, and/or collagenolysis activities (Lemsaddek et al., 2010). Proteolytic and keratinolytic activities of dermatophytes have been a subject of interest for several years to understand the pathogenicity of dermatophytosis (Venkatesan et al., 2002). The dermatophyte species within the three genera vary in their pathogenicity in vivo. Dermatophytes utilize keratin as a nutrient source; they usually do not invade viable tissue. However, all species colonize and invade the keratinized stratum corneum of the epidermis and the follicular ostium of hairs by secreting exo-enzyme keratinase and induces inflammatory reaction at the site of infection. The ability of different species to penetrate hair and nails varies widely (Lakshmipathy and Kannabiran, 2010; Dueka et al., 2002). Although the causes of this observed tissue specificity are unknown, but are thought to be due to individual organisms requires specific nutritional requirements or the enzyme production (Simpanya, 2000). Fungal conidia adhere to the stratum corneum's underlying substrate and begin to germinate 24 hours later. Ultrastructural observations revealed polymeric material is shown to mediate the adherence between microconidia and stratum corneum cells. As they develop further, germ tubes penetrate horizontally in and through the thickness of stratum corneum and causing skin infections. Invasion of the cornified cells of stratum corneum involves the elongation of the germ tubes by mechanical forces and production of different proteolytic and lipolytic exoenzymes (Straten et al., 2002) . The underlying and surrounding tissues are generally affected due to allergic or inflammatory host responses to the presence of the fungi. Inflammation causes the pathogen to migrate from the site of infection to a new location. This movement results in the classical ringed lesion. As long as the infection continues, the ringed lesion spreads outward (Dueka et al., 2002).

CLINICAL MANIFESTATIONS

Traditionally, the different types of dermatophytosis are classified and have been named according to the anatomic locations involved by using the Latin term designating the body site after the word tinea, e.g., tinea mannum for ringworm of the palm, tinea barbae– stands for the infection of the chin etc., Cutaneous dermatophytosis are usually identified by their scaly patches, with central clearing and sharply demarcated, annular, erythematous, advancing margins, vesicles, blisters and pustules (Stojanov et al., 2011).

Types of dermatophytosis and their clinical manifestations

Tinea capitis

Tinea capitis is the dermatophyte infection of the hair covering the head, eyelashes, and eyebrows, (Weitzman and Summerbell, 1995; Leung et al., 2020). It is predominantly caused by Microsporum sp. such as M, canis and M. audouinii and Trichophyton tonsurans (Trovato et al., 2006). Children between the ages of six and thirteen are typically affected with tinea capitis. Symptoms
include alopecia and lymphadenopathy, erythema or severe folliculitis, seborrheic-like scale, ‘black dot’ pattern and tiny pustules in the scalp (Gupta and Summerbell, 2000). Lesions could be non-inflammatory and persistent, or they could be inflammatory (Hay, 2000).

**Tinea corporis**

It is the dermatomycosis that appears on body, shoulders and legs. Tinea corporis includes all superficial dermatophyte infections of the glabrous skin, excluding the scalp, beard, face, hands, feet, and groin. (Gupta et al., 2003). Symptoms could be severe with clearly limited erythematous vesicular spo. It is caused by *Microsporum* sp, *Epidermophyton* sp and *Trichophyton* sp.

**Tinea cruris**

It is dermatophytic infection affecting perianal, perineal, genitalia, pubic area, and crotch region. It is commonly seen in older male persons. The symptoms are production of dry dandruff. Causative agents are *T. rubrum* and *E. floccosum* (Weitzman and Summerbell, 1995).

**Tinea favus**

Tinea favosa is a chronic inflammatory dermatophyte infection of the scalp, glabrous skin, and nails. It is commonly caused by *Trichophyton schoenleinii*. (Anane and Chtourou, 2013). Occasionally, *Trichophyton violaceum* or *Microsporum gypseum* may cause similar lesions (Tlmcani et al., 2016). Symptoms could be prominent yellow scabs and dry dandruff (Weitzman and Summerbell, 1995).

**Tinea imbricate**

It is a chronic infection of skin folds caused by a strictly anthropophilic dermatophyte *T concentricum*. Typically, the symptoms include appearance of several scaly, annular, and concentric rings that can extend to form polycyclic plaques with or without erythema. Later several overlapping lesions develop, and the plaques become lamellar with abundant thick scales adhering to one side, giving rise to the appearance of fish scales or overlapping roof tiles (Leung et al., 2018).

**Tinea manuum**

*Tinea manuum* is a dermatophyte infection of the palms and interdigital areas of hands. It can present with erythema and minimal scale on the dorsum of the hand (Tamer and Yoku, 2017). However, the symptoms of chronic tinea manuum include hyperkeratosis and cracking with or without mild itching of the skin (Tamer and Yuksel, 2017; Errichetti and Stinco, 2018). Its causative agent is *T. rubrum* (Weitzman and Summerbell, 1995).

**Tinea pedis** (Athlete’s foot)

It is the dermatophyte infection of the soles of feet and toes. It is also known as athletes foot. It is the most widely suffered dermatophyte infection. It could be chronic with squamose epithelia, thickening of stratum corneum, redness and inflammation. It is caused by *Epidermophyton floccosum* and *Trichophyton rubrum* (Weitzman and Summerbell, 1995; Johnson, 2002).

**Tinea unguium** (Onychomycosis)

It is a chronic dermatophytic infection of nails. It appears under nails or superficially (Hasan et al., 2004; Stojanov et al., 2011). It is commonly caused by *T. rubrum* and *T. interdigitale* (Asz-Sigall et al., 2017). It occurs at a higher frequency among the elderly population (Harada, 2011).

**Tinea barbae**

It is a ringworm of the beard and mustache (Weitzman and Summerbell, 1995). It affects the hairy part of the face – the beard, less often the moustache. It is caused predominantly by zoophilic dermatophytes, but in rare cases, pathogens can be also anthropophilic species, *Trichophyton rubrum* (Vazheva and Zisova, 2021).

**CONCLUSION**

Dermatophytooses are the most frequent fungal infections all over the world. It affecting individuals in various age groups. Many epidemiological studies have shown that the different forms of tinea are more prevalent in people of low socio-economic status and poor personal hygiene. Improvements in public health care and self-hygiene may play a major role in controlling these diseases.

**ETHICS APPROVAL AND CONSENT TO PARTICIPATE**

Not applicable.

**CONSENT FOR PUBLICATION**

Not applicable.

**FUNDING**

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

**DISCLOSURE OF INTEREST**

The authors declare that they have no competing interest.
REFERENCES


Coelho, A.C., Pinto, M.L., Coelho, A.M., et al., 2011. Laboratory Limits on Dermatophyte Diagnosis in Rabbits with Clinical Lesions. JAST, 1:608-612.


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