Corneal reinforcement using an acellular dermal matrix for an analysis of biocompatibility, mechanical properties, and transparency

Ziyuan Liu a, Jing Ji a, Jing Zhang a, Chen Huang b, Zhaojun Meng a, Weiqiang Qiu a, Xuemin Li a, Wei Wang a,⇑

a Department of Ophthalmology, Peking University Third Hospital, Key Laboratory of Vision Loss and Restoration, Ministry of Education, 49 North Garden Road, Haidian District, Beijing 100191, China
b Medical Research Center, Peking University Third Hospital, 49 North Garden Road, Haidian District, Beijing 100191, China

A R T I C L E   I N F O
Article history:
Received 7 November 2011
Received in revised form 4 May 2012
Accepted 7 May 2012
Available online 12 May 2012

Keywords:
Biocompatibility
Collagen
Cornea
Mechanical properties

A B S T R A C T
The aim of this study was to analyze the viability of using an acellular dermal matrix (ADM) as a reinforcement material for peripheral corneal thinning disease. The complete removal of cell components was confirmed by hematoxylin and eosin (H&E) and 4’,6-diamidino-2-phenylindole (DAPI) staining. Transmission electron microscopy determined that the stromal structure was well preserved. Uniaxial tests revealed that the ADM had strong mechanical properties. After being implanted into rabbit cornea the ADM showed no sign of rejection and even achieved good transparency 24 weeks post-surgery. H&E staining demonstrated that keratocytes grew in the ADM and the ADM–cornea interface became blurry. Picrosirius red staining revealed great changes of collagen in the ADM. Uniaxial testing of the reinforced cornea showed better mechanical strength than the normal rabbit cornea, but this did not exhibit statistical significance. These results suggest that ADM is a worthy candidate for future exploration as a reinforcement material for peripheral corneal thinning problems.

© 2012 Acta Materialia Inc. Published by Elsevier Ltd. All rights reserved.

1. Introduction

The cornea, the most important part of the outer ocular tunic, is a well-differentiated connective tissue mostly composed of extracellular matrix [1]. It serves as a physical barrier between the eyeball and the external environment, as well as being the primary refractive element in the optical pathway [2]. Most characteristics of the cornea, including its physical strength, stability of shape, and transparency, are largely attributed to the ultrastructure of collagen fibrils in the corneal stroma, which represents the largest portion, more than 70%, of the cornea’s dry weight [3]. The normal human corneal stroma is rich in type I collagen, and contains relatively large proportions of type V and VI collagens [4,5]. Type III collagen is present in low proportions but increases during wound healing, inflammation, and several pathological conditions [1]. The remarkable uniformity of fibril diameter and regularity of interfibrillar spacing are major determinants of corneal transparency [6,7]. The collagen fibril direction and orientation are closely related to corneal tensile strength, which provides protection against external trauma and maintains the corneal shape and curvature [8].

Progressive stromal thinning is the hallmark of several corneal ectatic disorders, such as keratoconus with central/para-central corneal thinning, as well as pellucid marginal degeneration and Terrien’s marginal degeneration with peripheral corneal thinning [9,10]. A localized or extensively thinned stroma results in bulging of the corneal surface and leads to high against the rule astigmatism. The poorer mechanical properties puts the thinning cornea at risk of rupture and perforation. Treatment consists of contact lenses in the early stages and keratoplasty with human donor material for severe cases to restore vision. However, sometimes the grafts are large and close to the limbus because of the location of the thinning, making surgery technically more difficult and the graft more prone to rejection [11,12]. Other factors that limit the worldwide use of corneal transplantation include the shortage of donor tissue as well as the risk of infectious disease transmission [3,13].

There has been major progress in corneal tissue engineering over the past few years. The idea of scaffolding in tissue engineering has been the inspiration for an acellular collagenous frame that could be used for corneal reinforcement. Such a scaffold must demonstrate several critical features for potential utility in vivo, including mechanical integrity, biocompatibility, slow biodegradation, and transparency.

An acellular dermal matrix (ADM) is a commercially available tissue graft derived from donated human skin [14,15]. ADM has