Biomechanical and morphological changes of rabbit corneas under collagenase type II and negative pressure: three months follow-up observation

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Abstract

Background: To investigate biomechanical and morphological changes of rabbit cornea ectasia induced by collagenase type II and negative pressure during 3 months after treatment.

Method: Eighteen New Zealand white rabbits were randomly and evenly arranged into three groups.

In group NP, the corneas were continuously attracted by negative pressure with 500 mmHg for 30 min, treated by every other day, three times in total. In group CII, the corneal central zone was soaked in the collagenase type II solution (200 μ L of 3 mg/ml) for 30 min. In group CP, the corneas were disposed as group CII firstly, then applied negative pressure as group NP for once after 5 days. All right eyes were treated as control eyes. Corneal morphology and biomechanical related parameters were observed in vivo once a week for three weeks after treatment and before execution. Histology and biomechanics were tested in vitro at the third month after treatment.

Results: Corneal diopter and corneal central thickness (CCT) changed to some extent after treatment immediately as a result of negative pressure in group NP. Three months after treatment, their elastic modulus increased and the relaxation degree decreased compared with the control one. In Group CII, corneal diopter increased, CCT and CH decreased at the second week after treatment, which showed the characters of ectatic corneas. At the third month after treatment, elastic modulus (E L) of the experimental eyes decreased slightly compared with the control eyes. Due to the large individual differences, there were no regular changes on experimental corneas in Group CP.

Conclusions: Cornea soaked with collagenase type II showed the obvious characteristics of ectatic cornea at the second week after treatment, but the characteristics disappeared gradually. Negative pressure can result in the change of corneal thickness and diopter in a short period of time, and the degree of swelling and duration are far less than Group CII, but the changes of biomechanical parameters are more obviously than Group CII.

Full Text

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed.

However, the manuscript can be downloaded and accessed as a PDF.

Figures

Figure 1

Diagram of the negative pressure device. The device is made up of the suction pump, 50 mL needle tubing, pressure sensor, hard connection pipeline and suction catheter. The air inside the device can be sucked out by suction pump to create a negative pressure environment.

Figure 2

The change of CCT (Δ CCT). (a) is negative pressure group (Group NP), Δ CCT of experimental eyes increased and then decreased slightly, which was no statistically significant compared with pre-treatment and the control group ($p = 0.063 > 0.05$; $p = 0.198 > 0.05$) after three months. (b) is group treated with collagenase type II (Group CII), Δ CCT of experimental eyes obviously decreased at the second week after treatment, and significantly different from pre-treatment and the control group ($p = 0.003 < 0.05$; $p = 0.01 < 0.05$). Then Δ CCT of experimental eyes recovered gradually and no significant differ from the control one ($p = 0.468 > 0.05$) at the third month after treatment. (c) is group treated with such two disposals, the mean values of CCT for experimental eyes were slightly thicker and then recovered, not statistically significant was observed compared with pre-treatment and control group ($p = 0.507 > 0.05$; $p = 0.748 > 0.05$). The solid points are experimental data, and the hollowed points are control one.

Figure 3

The change of corneal surface curvature for three groups. (a-c) and (d-f) are CC along the horizontal and vertical direction (ΔCC_H and ΔCC_V), respectively. In the Group NP, CC_H (a) was slight fluctuation post-treatment, and significantly differ from the pre-treatment at the third week ($p = 0.039 < 0.05$), while CC_V (d) was not ($p = 0.078 > 0.05$). In Group CII, the mean values of ΔCC_H (b) obviously decreased at the first week and then recovered, no obvious change on CC_V (e). In the Group CP, ΔCC_H (c) and ΔCC_V (f) increased immediately and then gradual growth, there was no significant difference between pre- and post-treatment of experimental eyes ($p = 0.533 > 0.05$ of CC_H , $p = 0.739 > 0.05$ of CC_V), as well as experimental eyes and control eyes ($p = 0.511 > 0.05$ of CC_H , $p = 0.811 > 0.05$ of CC_V) at the third month after treatment.

Figure 4

The changes of corneal mechanical properties in vivo for three groups. (a-c) and (d-f) are Δ CH and Δ CRF, respectively. In Group NP, Δ CH (a) increased slightly and then recovered, while Δ CRF (d) first decreased slightly. In Group CII, the mean values of Δ CH (b) for experimental cornea were significantly decreased compared with that of pre-treatment ($p = 0.021 < 0.05$), while no significant difference with control eye ($p = 0.345 > 0.05$) at the second week after treatment.

Figure 5

Stress-strain curves (a) and normalized stress relaxation curves (b) of corneal strips. These curves will be fitting to obtain mechanical parameters, EL, EH and parameter B were obtained by stress-strain curves. Stress relaxation time (τ) and relaxation limit $G(\infty)$ were obtained by normalized stress relaxation curves.

Figure 6

The biomechanical parameters of cornea in three groups. (a) and (c) are the results of the elastic modulus in the low and high stress region of strain-stress curves, (b) is the results of parameter B in the nonlinear region of strain-stress curves, (d) and (e) are the results of stress relaxation limit and relaxation time of corneas. In group NP, elastic modulus at low and high stress region (E_L and E_H , a and c) increased obviously, while conversely in parameter B (b). And the stress relaxation time (e) increased, which indicated that the relaxation stress of experimental corneas became slow down. In both Group CII and CP, no significant difference was observed in all the mechanical parameters between experimental and control corneas, and the differences in Group CP were slightly larger than those in Group CII.

Figure 7

Hematoxylin-eosin stained corneal sections. The structure of each layer was intact and no obvious abnormality in the cell morphology was observed in all group. Some epithelial cells were lost due to sectioning. No significant difference between the experimental and control corneas in Group NP (the first row), while the experimental corneas tissue sections showed loose and disordered collagenous fibers, widened interlamellar clefts compared with control corneas in Group CII and Group CP (the second and third row).

Supplementary Files

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