[DESCRIPTION]

[Title of Invention] THERAPEUTIC AGENT FOR KERATOCONJUNCTIVE DISORDERS

[Technical Field]

[0001]

The present invention relates to a therapeutic agent for a keratoconjunctive disorder containing a RARγ agonist as an effective ingredient.

[Background Art]

[0002]

The cornea is a transparent avascular tissue with a diameter of about 1 cm, covering the front surface of an eye ball. The conjunctiva is a mucous membrane covering the back surface of the eye lid and the surface of an eye ball which is posterior to the corneal limbus. The cornea and the conjunctiva serve an important role in vision. It is known that visual function is seriously affected when a disorder occurs therein. Keratoconjunctive disorders induced by various diseases such as corneal ulcer, keratitis, and dry eye are disorders caused by a delay in recovery from a disorder due to some reason such as an external injury or by a disorder that has become chronic. Since the cornea is a tissue that is connected to the conjunctiva, such diseases negatively affect each other in the normal construction of the epithelium and in some cases harm the structure or functioning of the corneal stroma or endothelium.

[0003]

Collagen (especially type I collagen) is known as one of the representative stromal components of corneal parenchymal tissue. A functional disorder resulting from stromal degradation occurs in diseases due to a keratoconjunctive disorder. Thus, suppression of degradation of collagen (especially type I collagen) is considered effective against diseases caused by a keratoconjunctive disorder.

[0004]

In a keratoconjunctive disorder, scar tissue, which is often formed after an inflammation has calmed, may obstruct the visual

function. For this reason, suppression of collagen contraction, if possible, is considered effective against contraction and formation of scars (hereinafter, referred together as "scar formation") as in the above-described suppression of collagen degradation.

[0005]

Patent Literature 1 describes that all-trans retinoic acid (hereinafter, also referred to as ATRA) promotes corneal regeneration. However, the effect thereof is weak and the detailed mechanism thereof is yet to be elucidated.

[0006]

Further, ATRA is an agonist of retinoic acid receptors (hereinafter, also referred to as RAR). However, since ATRA does not have selectivity with respect to RAR subtypes RARα, RARβ, and RARγ, the contribution of each RAR subtype to corneal regeneration effects is unknown.

[0007]

Meanwhile, RAR is involved in various effects such as growth, morphogenesis and differentiation in many cells, such as inflammatory cells, immune cells, and structural cells. Further, it is verified that there is a difference in the distribution of RAR subtypes depending on the tissue or organ of a mammal.

[0008]

Some of the effects of RAR are undesirable, such as increase in triglyceride due to RARα. Thus, the specificity or selectivity with respect to subtypes in compounds with RAR agonist activity is expected to lead to reduction in risk of side effects.

[0009]

For the above reasons, there is a demand for RAR agonists, which have a strong effect of suppressing keratoconjunctive disorders and are highly safe based on subtype selectivity.

[0010]

Patent Literatures 2 and 3 disclose the RAR agonist (E)-4-(2-{3-[(1H-pyrazole-1-yl)methyl]-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl}vinyl)benzoic acid and the derivatives thereof. Further, Patent Literature 2 describes that

(E)-4-(2-{3-[(1H-pyrazole-1-yl)methyl]-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl}vinyl)benzoic acid is useful against pulmonary emphysema, cancer, and dermatosis. Patent Literature 3 describes that the above-described agonist is useful against neurological pain.

[0011]

In addition, Non-Patent Literature 1 describes that the RAR agonist 6-[3-(1-adamantyl)-4-hydroxyphenyl]-2-naphthalene acid induces apoptosis in lung cancer cells.

[0012]

Furthermore, Patent Literature 4 describes that the RAR agonist 3-fluoro-4-[2-hydroxy-2-(5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl)acetylamino]benzoic acid is useful in muscle repair or regeneration.

[0013]

However, pharmacological effects on keratoconjunctive disorders or scar formation resulting from keratoconjunctive disorders are not discussed or reported for any of the RAR agonists. In addition, there is no literature that suggests such an effect.

[Citation List]

[Patent Literature]

[00014]

[PTL 1] Japanese Laid-Open Publication No. 2009-235031

[PTL 2] International Publication No. WO 2002/028810

[PTL 3] International Publication No. WO 2008/057930

[PTL 4] Japanese Laid-Open Publication No. 2013-536855

[Non Patent Literature]

[0015]

[NPL 1] Sun SY et al., Cancer Research 62(8): 2430-2436 (2002)

[Summary of Invention]

[Technical Problem]

[0016]

The search for a drug that is effective against ophthalmic diseases, especially keratoconjunctive disorders, is an objective that is important and of interest. The objective of the present invention is to provide a therapeutic agent that

has an effect of suppressing a keratoconjunctive disorder and is highly safe based on subtype selectivity.

[Solution to Problem]

[0017]

After diligent research to find a drug that is effective against keratoconjunctive disorders, the inventors discovered that the RARγ agonist (E)-4-(2-{3-[(1H-pyrazole-1-yl)methyl]-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl}vinyl)benzoic acid (R667: hereinafter, also referred to as "RARγ agonist A") exerts an excellent effect of ameliorating keratoconjunctive disorders as well as scar formation associated with keratoconjunctive disorders by pharmacological tests using rabbit keratocytes and subconjunctival fibroblasts, wherein a potent effect of suppressing collagen degradation as well as a significant effect of suppressing collagen contraction were demonstrated. Furthermore, it was discovered that other RARγ agonists, 6-[3-(1-adamantyl)-4-hydroxyphenyl]-2-naphthalene acid (CD437: hereinafter, also referred to as "RARγ agonist B") and 3-fluoro-4-[2-hydroxy-2-(5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl)acetylamino]benzoic acid (BMS961: hereinafter, also referred to as "RARγ agonist C") also exhibit a significant effect of suppressing collagen degradation in pharmacological tests using rabbit keratocytes to complete the present invention.

[0018]

Specifically, the present invention is [1] a therapeutic agent for a keratoconjunctive disorder, comprising a RARγ agonist as an effective ingredient, [2] the therapeutic agent of the above-described [1], wherein the RARγ agonist is (E)-4-(2-{3-[(1H-pyrazole-1-yl)methyl]-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl}vinyl)benzoic acid, 6-[3-(1-adamantyl)-4-hydroxyphenyl]-2-naphthalene acid, 3-fluoro-4-[2-hydroxy-2-(5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl)acetylamino]benzoic acid, an ester thereof, or a salt thereof, [3] the therapeutic agent of

above-described [1] or [2], wherein the keratoconjunctive disorder is selected from the group consisting of corneal ulcer, corneal epithelial abrasion, keratitis, dry eye, conjunctivitis, chronic superficial keratitis, corneal erosion, persistent corneal disorders, superficial punctate keratopathy, corneal epithelial defects, conjunctival epithelial defects, keratoconjunctivitis sicca, superior limbic keratoconjunctivitis, filamentary keratoconjunctivitis, infectious keratitis, noninfectious keratitis, infectious conjunctivitis, noninfectious conjunctivitis, corneal cicatrization, and conjunctival cicatrization, [4] the therapeutic agent according to any one of the above-described [1]-[3], wherein a form of administration is instillative administration or oral administration, and [5] the therapeutic agent accordingly to any one of the above-described [1]-[4], wherein a dosage form is an instillation, an ophthalmic ointment, an injection, a tablet, a granule, a fine granule, a powder or a capsule.

[Advantageous Effects of Invention]

[0019]

RARγ agonists, which are effective ingredients of the therapeutic agent for a keratoconjunctive disorder of the present invention, are useful as a therapeutic agent for keratoconjunctive disorders, such as corneal ulcer, corneal epithelial abrasion, keratitis, dry eye, conjunctivitis, chronic superficial keratitis, corneal erosion, persistent corneal disorders, superficial punctate keratopathy, corneal epithelial defects, conjunctival epithelial defects, keratoconjunctivitis sicca, superior limbic keratoconjunctivitis, filamentary keratoconjunctivitis, infectious keratitis, noninfectious keratitis, infectious conjunctivitis or noninfectious conjunctivitis, by strongly suppressing keratoconjunctive collagen degradation.

[0020]

Further, RARγ agonists, which are effective ingredients of the therapeutic agent for a keratoconjunctive disorder of the

present invention, are also useful as a therapeutic agent for corneal cicatrization or conjunctival cicatrization associated with a keratoconjunctive disorder by strongly suppressing keratoconjunctive collagen contraction.

[Brief Description of Drawings]

[0021]

[Figure 1] Figure **1** is a graph showing the relationship between the concentration (nM) of RARγ agonist A (R667) and collagen degradation (amount (μg) of hydroxyproline per well). The vertical axis represents the numerical value (%) when the amount of hydroxyproline of the control is set to 100.

[Figure 2] Figure **2** is a graph showing the relationship between the concentration (nM) of RARγ agonist A (R667) and collagen contraction (diameter (mm) of collagen gel in the dish) when using subconjunctival fibroblasts, wherein "*" indicates the presence of a statistically significant difference ($p < 0.05$).

[Figure 3] Figures **3** is a graph showing the relationship between the concentration (μM) of RARγ agonist A (R667) and collagen contraction (diameter (mm) of collagen gel in the dish) when using keratocytes, wherein "*" indicates the presence of a statistically significant difference ($p < 0.05$).

[Figure 4] Figure **4** is a graph showing the relationship of the concentrations (nM) of RARγ agonist A (R667), RARγ agonist B (CD437), and RARγ agonist C (BMS961) with respect to collagen degradation, when using keratocytes. The vertical axis represents the ratio (Ratio) of the amount (μg) of hydroxyproline per well when a RARγ agonist and a stimulant are added, in cases where the amount (μg) of hydroxyproline per well when a RARγ agonist and a stimulant are not added is set to 1, wherein "*" indicates the presence of a statistically significant difference ($p < 0.05$).

[Figure 5] Figures **5** shows the relationship between the concentration (μM) of RARγ agonist A (R667) and the expression and activation of matrix metalloproteinases (MMP) when using keratocytes. The top row of Figure **5A** shows the expression and activation of MMP-1, the bottom row of Figure **5A** shows the

expression and activation of MMP-3, and Figure **5B** shows the expression and activation of MMP-2 and MMP-9.

[Figure 6] Figure **6** shows the results of observation when a lipopolysaccharide (LPS) and a RARγ agonist A (R667) are administered into the corneal stroma in one eye of male Japanese white rabbits. The top row (Vehicle) is the result of administering only a solution that does not contain the RARγ agonist A (R667) of the present invention, and the bottom row (0.1% R667) is the result of administering a solution containing RARγ agonist A (R667).

[Description of Embodiments]

[0022]

The therapeutic agent for a keratoconjunctive disorder of the present invention is not particularly limited and may be any therapeutic agent having a RARγ agonist as the effective ingredient. The RARγ agonist of the present invention refers to a compound that can promote the activation of a RARγ receptor by binding to a RARγ receptor significantly in comparison to RAR α receptors or RAR β receptors.

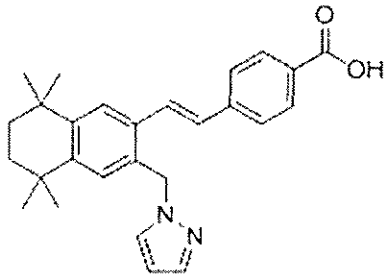
[0023]

Examples of such RARγ agonists include (E)-4-(2-{3-[(1H-pyrazole-1-yl)methyl]-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl}vinyl)benzoic acid (R667) represented by the following formula (I), 6-[3-(1-adamantyl)-4-hydroxyphenyl]-2-naphthalene acid (CD437) represented by the following formula (II), 3-fluoro-4-[2-hydroxy-2-(5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl)acetylamino]benzoic acid (BMS961) represented by the following formula (III), (2E)-3-(4-carboxyphenyl)-1-(5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl)-2-propene-1-one oxime (NRX204647: hereinafter, also referred to as "RARγ agonist D") represented by the following formula (IV), 4-[7-(1-adamantyl)-6-hydroxynaphthalene-2-yl] benzoic acid (CD1530: hereinafter, also referred to as "RARγ agonist E") represented by the following formula (V), esters of such

compounds (RARγ agonists A, B, C, D, and E), and salts of such compounds (RARγ agonists A, B, C, D, and E). Preferred examples of RARγ agonists include RARγ agonist A, RARγ agonist B, RARγ agonist C, esters of such compounds (RARγ agonists A, B, and C), and salts of such compounds (RARγ agonists A, B, and C).

[0024]

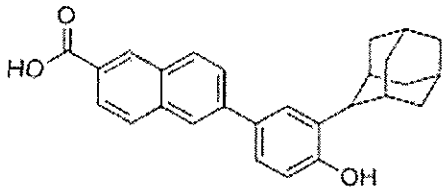
[Chemical 1]



(I)

[0025]

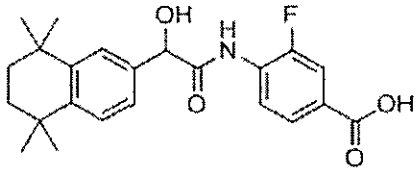
[Chemical 2]



(II)

[0026]

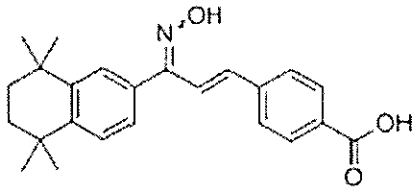
[Chemical 3]



(III)

[0027]

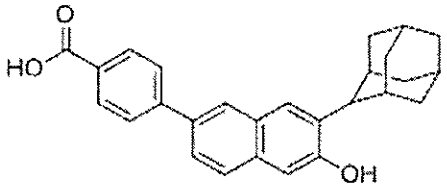
[Chemical 4]



(IV)

[0028]

[Chemical 5]



(V)

[0029]

Further, other embodiments of the present invention include a method of treating a keratoconjunctive disorder characterized by administering the RARγ agonist of the present invention to a subject, a RARγ agonist of the present invention for use as a therapeutic agent for a keratoconjunctive disorder, and use of the RARγ agonist of the present invention in the preparation of a therapeutic agent for a keratoconjunctive disorder.

[0030]

RARγ agonist A, which is one of the effective ingredients of the therapeutic agent for a keratoconjunctive disorder of the present invention, an ester thereof and a salt thereof are known compounds described in Patent Literature 2. They can be manufactured in accordance with the method described in Patent Literature 2 or purchased as a commercially-available product. Examples of the commercially-available products include product name: palovarotene manufactured by Shanghai Haoyuan Chemexpress.

[0031]

Among the effective ingredients of the therapeutic agents for a keratoconjunctive disorder of the present invention, RARγ agonist B is a known compound described in Non-Patent Literature 1 and Patent Literature 4, RARγ agonist C is a known compound described in Patent Literature 4, and RARγ agonists D and E are known compounds described in the following document (Shimono K. et al., Nat Med. 17(4): 454-460 (2011)). Said compounds, esters thereof and salts thereof can be manufactured in accordance with a conventional method or purchased as a commercially-available product. Examples of commercially available products include product name: CD437 (ab141305) manufactured by Abcam and product name: CD437 manufactured by Tocris Bioscience for RARγ agonist

B, product name: BMS961 manufactured by Tocris Bioscience for RARγ agonist C, and product name: CD1530 manufactured by Santa Cruz biotechnology and product name: CD1530 manufactured by Tocris Bioscience for RARγ agonist E.

[0032]

Esters in the aforementioned esters of RARγ agonists A, B, C, D, and E, which are effective ingredients of the therapeutic agent for a keratoconjunctive disorder of the present invention, are not particularly limited and may be any ester converted to RARγ agonists A, B, C, D, or E in a reaction by an enzyme or the like under physiological conditions in vivo. Such esters include: esters generated by reaction with a primary alcohol, such as methanol, ethanol, propanol, hexanol, or dodecanol; esters generated by reaction with a secondary alcohol such as isopropanol, s-butanol, or 1-ethylpropanol; esters generated by reaction with a tertiary alcohol such as t-butanol or 1-methyl-1-ethylpropanol; and esters generated by reaction with an amino alcohol such as 2-aminoethanol.

[0033]

The above-described esters can be manufactured by a known method from the aforementioned RARγ agonists A, B, C, D, E, or a synthetic intermediate thereof.

[0034]

Salts in the aforementioned salts of RARγ agonists A, B, C, D, and E, which are effective ingredients of the therapeutic agent for a keratoconjunctive disorder of the present invention, are not particularly limited and may be any pharmaceutically acceptable salts. Such salts include (1) as an acid addition salt, inorganic acid salts such as hydrochloride, hydrobromic acid salt, hydroiodic acid salt, nitric acid salt, sulfuric acid salt, and phosphoric acid salt; and organic acid salts such as acetic acid salt, trifluoroacetic acid salt, benzoic acid salt, oxalic acid salt, malonic acid salt, succinic acid salt, maleic acid salt, fumaric acid salt, tartaric acid salt, citric acid salt, methanesulfonic acid salt, ethanesulfonic acid salt, trifluoromethanesulfonic acid salt, benzenesulfonic acid salt,

p-toluenesulfonic acid salt, glutamic acid salt, and aspartic acid salt and (2) as a basic salt, metal salts such as sodium salt, potassium salt, calcium salt and magnesium salt; inorganic salts such as ammonium salt; and organic amine salts such as triethylamine salt and guanidine salt.

[0035]

In the present invention, a keratoconjunctive disorder refers to a condition where a cornea or a conjunctiva is damaged due to various factors such as an abnormality in lacrimal fluid, metabolic abnormality, or external injury. Examples thereof include corneal ulcer, corneal epithelial abrasion, keratitis, dry eye, conjunctivitis, chronic superficial keratitis, corneal erosion, persistent corneal disorders, superficial punctate keratopathy, corneal epithelial defects, conjunctival epithelial defects, keratoconjunctivitis sicca, superior limbic keratoconjunctivitis, filamentary keratoconjunctivitis, infectious keratitis, noninfectious keratitis, infectious conjunctivitis and noninfectious conjunctivitis. Suppressing action on collagen degradation exerts an excellent ameliorating effect. Further, in the present invention, corneal cicatrization (scar formation on the cornea) and conjunctival cicatrization (scar formation on the conjunctiva) associated with a keratoconjunctive disorder are also examples of keratoconjunctive disorders. Suppressing action on collagen contraction exerts an excellent ameliorating effect.

[0036]

The therapeutic agent for a keratoconjunctive disorder of the present invention can be administered orally or parenterally (intravenous administration, intramuscular administration, intraperitoneal administration, percutaneous administration, intratracheal administration, intracutaneous administration, or subcutaneous administration) in a form of a tablet, capsule, powder, syrup, granule, fine granule, pill, liquid formulation, suspension, emulsion, percutaneous absorption agent, suppository, ointment (preferably ophthalmic ointment), lotion, inhalant, or injection manufactured by mixing in a suitable

pharmacologically acceptable additive.

[0037]

These formulations are manufactured by a well-known method by using an additive such as an excipient, lubricant, binding agent, disintegrator, emulsifier, stabilizer, flavoring agent or diluent.

[0038]

Examples of excipients include organic excipients and inorganic excipients. Examples of organic excipients include: sugar derivatives such as lactose, sucrose, glucose, mannitol, and sorbitol; starch derivatives such as corn starch, potato starch, α-starch and dextrin; cellulose derivatives such as crystalline cellulose; gum arabic; dextran; and pullulan. Examples of inorganic excipients include: light anhydrous silicic acid; and sulfuric acid salts such as calcium sulfate.

[0039]

Examples of lubricants include: stearic acid; metal salts of stearic acid such as calcium stearate and magnesium stearate; talc; colloidal silica; wax such as beeswax and spermaceti; boric acid; adipic acid; sulfuric acid salts such as sodium sulfate; glycol; fumaric acid; sodium benzoate; D,L-Leucine, sodium lauryl sulfate; silicic acids such as silica and silicic acid hydrate; and the starch derivatives for the above-described excipients.

[0040]

Examples of binding agents include hydroxypropyl cellulose, hydroxypropyl methylcellulose, polyvinylpyrrolidone, macrogol and the compounds described above shown for excipients.

[0041]

Examples of disintegrators include: cellulose derivatives such as hydroxypropyl cellulose with a low degree of substitutions, carboxymethyl cellulose, calcium carboxymethyl cellulose, and internally crosslinked calcium carboxymethyl cellulose; crosslinked polyvinylpyrrolidone; and chemically modified starch or cellulose derivatives such as carboxymethyl starch and sodium carboxymethyl starch.

[0042]

Examples of emulsifiers include: colloidal clay such as bentonite and veegum; anionic surfactants such as sodium lauryl sulfate; cationic surfactants such as benzalkonium chloride; and non-ionic surfactants such as polyoxyethylene alkyl ether, polyoxyethylene sorbitan fatty acid ester, and sucrose fatty acid ester.

[0043]

Examples of stabilizers include: para-hydroxybenzoic acid esters such as methylparaben and propylparaben; alcohols such as chlorobutanol, benzyl alcohol, and phenylethyl alcohol; benzalkonium chloride; phenols such as phenol and cresol; thimerosal; acetic anhydride; and sorbic acid.

[0044]

Examples of flavoring agents include: sweeteners such as sodium saccharin and aspartame; acidulants such as citric acid, malic acid, and tartaric acid; and flavors such as lemon extract and orange extract.

[0045]

Diluents are generally compounds used as a diluent. Examples thereof include lactose, mannitol, glucose, sucrose, calcium sulfate, hydroxypropyl cellulose, microcrystalline cellulose, water, ethanol, polyethylene glycol, propylene glycol, glycerin, starch, polyvinylpyrrolidone, and mixtures thereof.

[0046]

The therapeutic agent for a keratoconjunctive disorder of the present invention includes those in a form of instillation in addition to the above-described dosage forms. The agent can be formulated with a well-known method by suitably blending in an isotonizing agent, buffer, pH regulator, solubilizer, thickener, stabilizer, preservative (antiseptic) or the like as an additive. Further, it is also possible to obtain a stable instillation by adding a pH regulator, thickener, dispersant or the like to prepare suspension of a drug.

[0047]

Examples of isotonizing agents include glycerin, propylene

glycol, sodium chloride, potassium chloride, sorbitol and mannitol.

[0048]

Examples of buffers include phosphoric acid, phosphate, citric acid, acetic acid, and ε-aminocaproic acid.

[0049]

Examples of pH regulators include hydrochloric acid, citric acid, phosphoric acid, acetic acid, sodium hydroxide, potassium hydroxide, boric acid, borax, disodium hydrogen phosphate, sodium dihydrogen phosphate, sodium carbonate, and sodium bicarbonate.

[0050]

Examples of solubilizers include polysorbate 80, polyoxylethylene hydrogenated castor oil 60, and macrogol 4000.

[0051]

Examples of thickeners and dispersants include: cellulose polymers such as hydroxypropyl methylcellulose and hydroxypropyl cellulose; polyvinyl alcohols; and polyvinylpyrrolidone. Further, examples of stabilizers include edetic acid and sodium edetate.

[0052]

Examples of preservatives (antiseptics) include commonly-used sorbic acid, potassium sorbate, benzalkonium chloride, benzethonium chloride, methyl parahydroxybenzoate, propyl parahydroxybenzoate, and chlorobutanol. It is also possible to use these preservatives in combination.

[0053]

An instillation may have any pH within a range acceptable for an ophthalmic formulation, but the pH is desirably set to 4.0-8.5.

[0054]

For ointments (preferably ophthalmic ointments), a commonly-used base such as white petrolatum or liquid paraffin can be used for preparation.

[0055]

The dosage of the therapeutic agent for a keratoconjunctive

disorder of the present invention can be appropriately changed in accordance with the dosage form, severity of symptoms of a patient to whom the agent is to be administered, age, weight, judgment of a physician or the like. For oral agents, it is generally possible to administer 0.01-5000 mg, preferably 0.1-2500 mg, and more preferably 0.5-1000 mg per day for an adult in one or several doses. For instillations, it is possible to administer those with an effective ingredient concentration of 0.000001-10% (W/V), preferably 0.00001-3% (W/V), and more preferably 0.0001-1% (W/V), in one or several daily doses. For ophthalmic ointments, it is possible to administer those with an effective ingredient concentration of 0.00001-10% (W/W), preferably 0.0001-3% (W/W), and more preferably 0.001-1% (W/W), in one or several daily doses.

[0056]

Hereinafter, the present invention is explained in further detail while providing Examples (Test Examples and Formulation Examples). However, the scope of the present invention is not limited thereto.

(Example 1)

[0057]

(Test Example) Test on suppression of three-dimensional collagen gel degradation in normal rabbit primary keratocytes by RARγ agonist A

Normal rabbit corneal cells were used to assess the suppression effect of a tested compound on three-dimensional collagen gel degradation in accordance with the method of Nishida et al (Investigative Ophthalmology & Visual Science 42: 1247-1253 (2001)).

[0058]

Primary keratocytes collected from a normal rabbit eye ball was grown to a confluent state and detached from a culture slide with 0.05% Trypsin-EDTA. After washing in a serum free medium (product number 11095; Gibco), the number of cells were counted. The obtained primary keratocytes were mixed with the type I collagen solution Cellmatrix Type I-A (product number 637-00653;

Nitta Gelatin Inc.) and Reconstitution Buffer (product number 635-00791; Nitta Gelatin Inc.) and dispensed into a 24-well plate so that the final concentration would be 1×10^5 cells/well to make a collagen gel.

[0059]

After making the gel, culture was started (under conditions of 37°C and 5% CO_2) by adding to a MEM medium a RARγ agonist A (R667)-containing dimethyl sulfoxide solution (R667 concentration: 0.1 nM, 1 nM, 10 nM, 100 nM, or 1000 nM) or a RARγ agonist-free dimethyl sulfoxide solution as a control and 10 ng (final concentration 10 ng/ml) of IL-1β (product number 201-LB-005; R&D Systems) and 60 µg (final concentration 60 µg/ml) of Plasminogen (product number P9156; Sigma) as a stimulant, and overlaying the medium on the previously prepared collagen gel.

[0060]

After 48 hours of culturing, the supernatant was ultrafiltrated, 100 µl of concentrated hydrochloric acid was added and heated, and the collagen was hydrolyzed. The reaction solution after the hydrolysis was dried under a nitrogen gas atmosphere by using a Dry Thermo Unit (DTU-2C, Taitec Co. Ltd.) and an evaporation head (E1-20 Taitec Co. Ltd.) and then dissolved in 500 µl of ultrapure water. The amount of hydroxyproline, which is the collagen degradation product in the solution, was measured in accordance with the method of Bergman et al (Analytical Chemistry 35(12): 1961-1965 (1963)) to assess the effect of suppressing collagen degradation of RARγ agonist A. The results are shown in Figure **1**.

[0061]

In the present test, RARγ agonist A exhibited a dosage-dependent effect of suppressing keratoconjunctive collagen degradation.

[0062]

(Formulation Example)

[0063]

(Drug Formulation Example 1) Instillation

In 100 ml	
RARγ agonist A	100 mg
Sodium chloride	800 mg
Polysorbate 80	appropriate amount
Disodium hydrogen phosphate	appropriate amount
Sodium dihydrogen phosphate	appropriate amount
Sterile purified water	appropriate amount

RARγ agonist A and the other components described above are added to sterile purified water. The solution is thoroughly mixed to prepare an instillation. It is possible to prepare an instillation with a concentration of 0.05% (W/V), 0.3% (W/V), 0.5% (W/V), or 1% (W/V) by changing the amount of RARγ agonist A or the like that is added.

[0064]

(Drug Formulation Example 2) Ophthalmic Ointment

In 100 g	
RARγ agonist A	0.3 g
Liquid paraffin	10.0 g
White petrolatum	appropriate amount

RARγ agonist A is added to homogeneously-melted white petrolatum and liquid paraffin. The mixture is thoroughly mixed and then gradually cooled to prepare an ophthalmic ointment. It is possible to prepare an ophthalmic ointment with a concentration of 0.05% (W/W), 0.1% (W/W), 0.5% (W/W), or 1% (W/W) by changing the amount of RARγ agonist A or the like that is added.

[0065]

(Drug Formulation Example 3) Tablet

In 100 mg	
RARγ agonist A	1 mg
Lactose	66.4 mg
Corn starch	20 mg
Calcium carboxymethyl cellulose	6 mg
Hydroxypropyl cellulose	6 mg
Magnesium stearate	0.6 mg

RARγ agonist A, corn starch and lactose are mixed in a mixer. Calcium carboxymethyl cellulose and hydroxypropyl cellulose are added to the mixture for granulation. The particle size of the resulting granules is adjusted after drying. Magnesium stearate is added to and mixed with the adjusted granules and the mixture is made into tablets with a tableting machine. Further, it is possible to prepare tablets with the content of 0.1 mg, 10 mg, or 50 mg in 100 mg by changing the amount of RARγ agonist A or the like that is added.

Example 2

[0066]

(Test Example) Test on suppression of three-dimensional collagen gel contraction in various primary cells derived from normal rabbits by RARγ agonist A.

Primary subconjunctival fibroblasts and primary keratocytes were used to assess the suppression effect of a tested compound on three-dimensional collagen gel contraction in accordance with the method of Nishida et al.

[0067]

As in Example 1, primary subconjunctival fibroblasts were grown and detached from a culture slide. After washing, a cell suspension was made. The resulting suspension (1.1×10^7 cells/well MEM), type I collagen solution (5 mg/ml), 10 × MEM, Reconstitution Buffer, and water were mixed on ice at 0.2:7:1:1:1.8 (volume ratio). A culture dish coated with 1% BSA was inoculated with 0.5 ml of the mixture, which was incubated for one hour at 37°C to make a collagen gel.

[0068]

Then, 0.5 ml of serum free media, to which a certain amount (1 ng/ml) of TGF-β1 (R&D Systems) and RARγ agonist A at each of the concentrations 1 nM, 10 nM, and 100 nM were added, were each added onto the above-described gel. The gel, together with a gel to which an agent-free serum-free medium was added, was continuously incubated at 37°C. The diameter of gels was measured from the time when 24 hours has past. The results of measuring the diameters of the gels after 48 hours are shown in Figure

2.

[0069]

The gel diameter was measured for primary keratocytes in a similar manner to the primary subconjunctival fibroblasts. The results are shown in Figure 3.

[0070]

It can be seen from Figures 2 and 3 that RARγ agonist A not only can suppress collagen degradation, but also collagen gel contraction due to TGF using subconjunctival fibroblasts or keratocytes. This demonstrates that RARγ agonist A contributes to collagen turn over and has an effect of suppressing tissue remodeling that occurs after inflammation, hemorrhage, infection, surgery, or injury in an ophthalmic tissue, i.e., fibrillation or cicatrization.

Example 3

[0071]

(Test Example) Test on suppression of three-dimensional collagen gel degradation in primary keratocytes derived from normal rabbits by RARγ agonist A, B, or C.

Primary keratocytes were used to assess the suppression effect of a tested compound on three-dimensional collagen gel degradation by the same method as in Example 1 in accordance with the method of Nishida et al.

[0072]

As in Example 1, primary keratocytes were grown and detached from a culture slide. After washing, a cell suspension was made. The resulting suspension (1.1×10^7 cells/well MEM), type I collagen solution (5 mg/ml), 10 × MEM, Reconstitution Buffer, and water were mixed on ice at 0.2:7:1:1:1.8 (volume ratio). A culture dish coated with 1% BSA was inoculated with 0.5 ml of the mixture, which was incubated for one hour at 37°C to make a collagen gel.

[0073]

After making the gel, culture was started (under conditions of 37°C and 5% CO_2) by adding to a MEM medium a RARγ agonist A (R667)-containing dimethyl sulfoxide solution (1 nM), RARγ

agonist B (CD437)-containing dimethyl sulfoxide solution (1 nM, 10 nM), RARγ agonist C (BMS961)-containing dimethyl sulfoxide solution (10 nM), or a RARγ agonist-free dimethyl sulfoxide solution as a control, and 10 ng (final concentration 10 ng/ml) of IL-1β (product number 201-LB-005; R&D Systems) and 60 μg (final concentration 60 μg/ml) of Plasminogen (product number P9156, Sigma Aldrich) as a stimulant, and overlaying the medium on the previously prepared collagen gel.

[0074]

After 48 hours of culturing, collagen was hydrolyzed and the amount of hydroxyproline, which is the collagen degradation product, was measured by the same method as Example 1 to assess the effect of suppressing collagen degradation of each RARγ agonist. The results are shown in Figure **4**.

[0075]

In the present test, not only RARγ agonist A, but also RARγ agonists B and C exhibited an effect of suppressing keratoconjunctive collagen degradation.

Example 4

[0076]

(Test Example) Test on suppression of the expression and activation of MMP-1, 2, 3, and 9 by RARγ agonist A

It is believed that secretion or expression of protease, i.e., matrix metalloproteinases (MMP), is associated with the degradation of type I collagen. In this regard, suppression of expression and activation of MMP-1, 2, 3, and 9 by RARγ agonist A was investigated.

[0077]

Primary keratocytes collected from a normal rabbit eye ball were cultured for 24 hours in a serum-free MEM medium. RARγ agonist A (R667) (R667 concentration: 1×10^{-6} μM, 1×10^{-5} μM, 1×10^{-4} μM, 1×10^{-3} μM, 1×10^{-2} μM) was added to the obtained culture solution and 12 hours of pre-treatment was performed. As a positive control, 10 nM of dexamethasone (Dex), which is a synthetic steroid, was added and pre-treatment was similarly performed. Then, IL-1β (0.1 ng/ml) was added for stimulation,

and the supernatant was collected after 24 hours. The following western blot analysis and gelatin zymography analysis were used on the collected culture solution.

[0078]

(Western blot analysis)

After developing the supernatant of the collected culture solution in SDS-PAGE using 10% polyacrylamide gel, the separated proteins were transferred onto a nitrocellulose filter. Then, non-specific sites on the nitrocellulose filter were blocked and incubated for 24 hours at 4°C with anti-human MMP-1 antibodies (R&D Systems) and anti-rabbit MMP-3 antibodies (Daiichi Fine Chemical Co., Ltd). ECL® reagent (GE Healthcare) was used for detection.

[0079]

The results are shown in Figure **5A**. The band for each of the non-active Pro-MMP-1, Pro-MMP-3 and active MMP-1, MMP-3 was diminished, where the extent thereof was dependent on the concentration of RARγ agonist A. Thus, it was revealed that RARγ agonist A concentration-dependently suppresses the expression and activation of MMP-1 and MMP-3.

[0080]

(Gelatin zymography analysis)

After developing the supernatant of the collected culture solution on SDS-PAGE using 10% polyacrylamide gel containing 0.1% of gelatin, it was incubated for one hour at room temperature with a TBS solution containing 2.5% Triton X-100. The gel after incubation was dyed with a solution of Coomassie Brilliant Blue (Wako Pure Chemical Industries, Ltd.) and decolored with a 5% methanol-7.5% acetic acid solution (Nacalai Tesque, Inc).

[0081]

The results are shown in Figure **5B**. The band for each of the non-active Pro-MMP-2, Pro-MMP-9 and active MMP-2, MMP-9 was diminished, where the extent thereof was dependent on the concentration of RARγ agonist A. Thus, it was revealed that RARγ agonist A concentration-dependently suppresses the expression and activation of MMP-2 and MMP-9.

Example 5

[0082]

(Test Example) Test on suppression of corneal opacity and ulceration with RARγ agonist A

Systemic anesthesia was applied to male Japanese white rabbits (body weight 2.5-3.5 kg, 27 rabbits) by intramuscular administration of a solution of a mixture of ketamine and xylazine. Then, topical anesthesia was applied by a 0.4% oxybuprocaine hydrochloride instillation. Furthermore, 30 µl of 1% LPS (Sigma Aldrich) was injected into the corneal stroma of one eye, but not in the other eye.

[0083]

50 µl of 0.1% PBS/0.1% polysorbate 80 solution containing RARγ agonist A (R667: 0.1%, 24 mM) was instillatively administered to the rabbits injected with LPS twice after the injection on the day of LPS injection and four times daily thereafter until day 10 by using a micropipette . As a control, a 0.1% PBS/0.1% polysorbate 80 solution free of RARγ agonist A (Vehicle) was similarly administered. Figure **6** shows representative examples of a control and a case where RARγ agonist A was administered.

[0084]

In Figure **6**, corneal opacity and ulceration were observed in the control (Vehicle) shown in the top row. However, in a case where RARγ agonist A was administered (0.1% R667) shown in the bottom row, corneal opacity and ulceration were not observed. Thus, it was revealed that RARγ agonist A suppresses corneal opacity and ulceration.

[Industrial Applicability]

[0085]

RARγ agonists, which are effective ingredients of the therapeutic agent for a keratoconjunctive disorder of the present invention, are useful in preventing or as a therapeutic agent for keratoconjunctive disorders, such as corneal ulcer, corneal epithelial abrasion, keratitis, dry eye, conjunctivitis, chronic superficial keratitis, corneal erosion, persistent

corneal disorders, superficial punctate keratopathy, corneal epithelial defects, conjunctival epithelial defects, keratoconjunctivitis sicca, superior limbic keratoconjunctivitis, filamentary keratoconjunctivitis, infectious keratitis, noninfectious keratitis, infectious conjunctivitis and noninfectious conjunctivitis, by strongly suppressing collagen degradation. Further, said RARγ agonists are also useful as a therapeutic agent for corneal cicatrization or conjunctival cicatrization associated with a keratoconjunctive disorder by strongly suppressing collagen contraction.

[Claims]

1. A method of reducing scar formation in a subject having a keratoconjunctive disorder, said method comprising administering to said subject an RARγ agonist, or an ester or salt thereof, in an amount effective to reduce scar formation.

2. A method of suppressing collagen degradation and/or collagen contraction in a subject having a keratoconjunctive disorder, said method comprising administering to said subject an RARγ agonist, or an ester or salt thereof, in an amount effective to suppress collagen degradation and/or collagen contraction.

3. The method of any one of claims 1 or 2, wherein said keratoconjunctive disorder is selected from the group consisting of corneal ulcer, corneal epithelial abrasion, keratitis, dry eye, conjunctivitis, chronic superficial keratitis, corneal erosion, persistent corneal disorders, superficial punctate keratopathy, corneal epithelial defects, conjunctival epithelial defects, keratoconjunctivitis sicca, superior limbic keratoconjunctivitis, filamentary keratoconjunctivitis, infectious keratitis, noninfectious keratitis, infectious conjunctivitis, noninfectious conjunctivitis, corneal cicatrization, and conjunctival cicatrization.

4. The method of claim 3, wherein said keratoconjunctive disorder is dry eye.

5. The method of claim 3, wherein said keratoconjunctive disorder is keratoconjunctivitis sicca.

6. The method of claim 3, wherein said keratoconjunctive disorder is corneal cicatrization.

7. The method of claim 3, wherein said keratoconjunctive disorder is conjunctival cicatrization.

8. A method of reducing scar formation on the conjunctiva and/or cornea of a subject, comprising administering to said subject an RARγ agonist, or an ester or salt thereof, in an amount effective to reduce scar formation, wherein said scar formation on the conjunctiva and/or cornea is caused by an external injury.

9. The method of claim 8, wherein said external injury is surgery.

10. The method of any one of claims 1-9, wherein said RARγ agonist is (E)-4-(2-{3-[(1H-pyrazole-1-yl)methyl]-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl}vinyl)benzoic acid, 6-[3-(1-adamantyl)-4-hydroxyphenyl]-2-naphthalene acid, 3-fluoro-4-[2-hydroxy-2-(5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl)acetylamino]benzoic acid, (2E)-3-(4-carboxyphenyl)-1-(5,5,8,8-

tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl)-2-propene-1-one oxime, 4-[7-(1-adamantyl)-6-hydroxynaphthalene-2-yl] benzoic acid, an ester thereof, or a salt thereof.

11. The method of claim 10, wherein said RARγ agonist is (E)-4-(2-{3-[(1H-pyrazole-1-yl)methyl]-5,5,8,8-tetramethyl-5,6,7,8-tetrahydronaphthalene-2-yl}vinyl)benzoic acid, an ester thereof, or a salt thereof.

12. The method of any one of claims 1-11, wherein said administering comprises administering orally or parenterally, intravenously, intramuscularly, intraperitoneally, percutaneously, intratracheally, intracutaneously, subcutaneously, or by instillation.

13. The method of any one of claims 1-12, wherein said RARγ agonist is in the form of a tablet, capsule, powder, syrup, granule, fine granule, pill, liquid formulation, suspension, emulsion, percutaneous absorption agent, suppository, ointment, lotion, inhalant, injection, or instillation.

14. The method of claim 13, wherein said ointment is an ophthalmic ointment.

15. The method of claim 14, wherein the concentration of said RARγ agonist in the ophthalmic ointment administered to said subject is from 0.00001% to 10% (w/v).

16. The method of claim 15, wherein the concentration of said RARγ agonist in the ophthalmic ointment administered to said subject is from 0.0001% to 3% (w/v).

17. The method of claim 16, wherein the concentration of said RARγ agonist in the ophthalmic ointment administered to said subject is from 0.001% to 1% (w/v).

18. The method of claim 12, wherein said administering is administering by instillation.

19. The method of claim 18, wherein the concentration of said RARγ agonist in the instillation administered to said subject is from 0.000001% to 10% (w/v).

20. The method of claim 19, wherein the concentration of said RARγ agonist in the instillation administered to said subject is from 0.00001% to 3% (w/v).

21. The method of claim 20, wherein the concentration of said RARγ agonist in the instillation administered to said subject is from 0.0001% to 1% (w/v).

22. The method of any one of claims 1-21, wherein said RARγ agonist is administered to said subject in one or more daily doses.