

[Document Name] Specification

[Title of the Invention]

PROTEOGLYCAN-CONTAINING MICRONEEDLE ARRAY

5 [Technical Field]

[0001]

The present invention relates to a microneedle array that can be used as an external preparation. More specifically, the present invention relates to a
10 microneedle array that is cosmetically or pharmaceutically effective.

[Prior Art]

[0002]

15 External preparations containing medicinal properties are conventionally used so that the medicinal properties may exhibit pharmacological activity under the skin. Solutions, ointments, cream preparations, tape preparations, patches, poultices, etc., are known as such
20 external preparations. These are topically applied or attached, so that medicinal properties are percutaneously absorbed to thereby exhibit desired pharmacological activity under the skin.

[0003]

25 However, such external preparations in an applied or attached form have drawbacks, i.e., they might be removed or lost due to sweating, washing, external pressure, and other factors while in use before the medicinal properties are percutaneously absorbed. Another
30 problem of these external preparations is that the medicinal properties are not percutaneously absorbed to a sufficient degree because of the barrier function of the skin, and hence they fail to exhibit the desired pharmacological activity. Particularly, when polymer
35 compounds are used as medicinal properties, percutaneous

absorption is difficult, thus making it difficult for the external preparations to exhibit the desired pharmacological activity.

[0004]

5 Recently, as a technique for solving these drawbacks of external preparations, microneedle arrays having microneedles comprising medicinal properties are being actively studied (Patent Documents 1 to 3). For example, Patent Document 1 proposes a microneedle array
10 having microneedles formed of a raw material mainly composed of collagen. According to the microneedle array of Patent Document 1, the microneedles are inserted into the skin surface layer and/or stratum corneum to supply the medicinal properties contained in the microneedles
15 under the skin. The inserted portions of the microneedles can dissolve or biodegrade under the skin and thus disappear. Further, when the microneedles of Patent Document 1, which have very fine needle parts, are inserted into the skin surface layer and/or stratum
20 corneum, neither pain nor bleeding occurs, and puncture wounds close quickly. The microneedles of Patent Document 1 are thus suitable for supplying medicinal properties under the skin.

[0005]

25 At the same time, microneedle arrays are required to have optimal designs depending on skin diseases or skin conditions. There is thus a demand for various kinds of microneedle arrays. However, the microneedles of microneedle arrays used as external
30 preparations are required to comprehensively have the following properties: (1) the strength to withstand insertion into the skin surface layer and/or stratum corneum, (2) the fineness and flexibility to cause no pain or bleeding in the skin surface layer and/or stratum
35 corneum at the insertion site of the microneedles, and (3)

solubility or biodegradability in the body of the microneedle portions under the skin. Accordingly, it is very difficult to change the design of the constituent materials of microneedle arrays, and this is particularly true for the main constituent material of the microneedles. For these reasons, only a few constituent materials for microneedle arrays have been reported at present.

[0006]

In recent years, medical or cosmetic applications of proteoglycan have attracted attention. Proteoglycan is known as a glycoconjugate composed of a core protein and glycosaminoglycan (acid mucopolysaccharide) bonded thereto. Proteoglycan is the principal constituent of the extracellular matrix, and is present in skin tissue, cartilage tissue, bone tissue, vascular tissue, etc. Proteoglycan is reportedly involved with the growth and bonding of subcutaneous cells. Moreover, proteoglycan is reportedly useful in preventing or treating inflammatory diseases or autoimmune diseases, preventing rejection after organ transplantation, preventing or improving allergies, and preventing or improving diabetes (see Patent Document 4).

[0007]

However, using proteoglycan in microneedle arrays has not been studied. At present, there is no clue as to whether proteoglycan can be used to form microneedles.

[Prior Art Documents]

[Patent Documents]

[0008]

Patent Document 1: Japanese Unexamined Patent Publication No. 2009-273872

Patent Document 2: Japanese Unexamined Patent Publication

No. 2009-254765

Patent Document 3: Japanese Unexamined Patent Publication
No. 2009-201956

Patent Document 4: Japanese Unexamined Patent Publication
No. 2007-131548

5 Patent Document 5: Japanese Unexamined Patent Publication
No. 2003-300858

[Non-Patent Document]

[0009]Non-Patent Document 1: Watanabe H, Yamada Y, Kimata K.,
Roles of aggrecan, a large chondroitin sulfate proteoglycan, in
10 cartilage structure and function.;J Biochem. 1998
Oct;124(4):687-93.

Non-Patent Document 2: Ota S, Yoshihara S, Ishido K, Tanaka M,
Takagaki K, Sasaki M., Effects of proteoglycan on dextran
sulfate sodium-induced experimental colitis in rats.Ota S; Dig
15 Dis Sci. 2008 Dec;53(12):3176-83. Epub 2008 May 8.

Non-Patent Document 3: Mitsui T, Sashinami H, Sato F, Kijima
H, Ishiguro Y, Fukuda S, Yoshihara S, Hakamada K, Nakane A,
Salmon cartilage proteoglycan suppresses mouse experimental
colitis through induction of Foxp3+ regulatory T cells.;
20 Biochem Biophys Res Commun. 2010 Nov 12;402(2):209-15. Epub
2010 Oct 20.

Non-Patent Document 4: Sashinami H, Takagaki K, Nakane A.,
Salmon cartilage proteoglycan modulates cytokine responses to
Escherichia coli in mouse macrophages.; Biochem Biophys Res
25 Commun. 2006 Dec 29;351(4):1005-10. Epub 2006 Nov 3.

[Summary of the Invention]

[Problem to Be Solved by the Invention]

[0010]

30 An object of the present invention is to provide
a novel and unprecedented microneedle array. More
specifically, an object of the present invention is to
provide a novel microneedle array comprising one or more
microneedles that have the following properties:

35 (1) the strength to withstand insertion into the

skin surface layer and/or stratum corneum,

(2) the fineness and flexibility to cause no pain or bleeding in the skin surface layer and/or stratum corneum at the insertion site of the microneedles, and

5 (3) solubility or biodegradability in the body of the microneedle portions under the skin.

[Means for Solving the Problem]

[0011]

10 The present inventors conducted extensive studies to solve the above problems, and surprisingly found that proteoglycan can be used as a base material to form microneedles, and that a microneedle array having the microneedles can be produced. The present inventors also
15 found that the microneedle array has the excellent properties described above in items (1) to (3), and is highly useful as an external preparation. Additionally, the microneedle array is expected to effectively exhibit proteoglycan-based useful pharmacological activity under
20 the skin.

The present invention was accomplished by conducting further studies based on these findings.

[0012]

25 More specifically, the present invention provides a microneedle array and a production method thereof according to the following embodiments:

[0013]

(I) Microneedle Array

(I-1). A microneedle array comprising one or more
30 microneedles formed on the surface of a substrate, the microneedles containing proteoglycan as a base material.

(I-2). The microneedle array according to (I-1), wherein each of the microneedles has a konide-like shape or a circular truncated cone shape.

35 (I-3). The microneedle array according to (I-1) or (I-2),

wherein each of the microneedles is a solid needle.

(I-4). The microneedle array according to any one of (I-1) to (I-3), wherein each of the microneedles has a root diameter of 120 to 400 μm , a tip diameter of 5 to 100 μm ,
5 and a length of 100 to 5000 μm , and the pitch (the distance from tip to tip) between adjacent microneedles is 100 to 1800 μm .

(I-5). The microneedle array according to (I-4), wherein each of the microneedles has a length of 100 to 1600 μm or
10 100 to 1000 μm .

(I-6). The microneedle array according to (I-4), wherein each of the microneedles has a length of more than 1000 μm but not more than 5000 μm , or more than 1000 μm but not more than 3000 μm .

15 (I-7). The microneedle array according to (I-4), wherein each of the microneedles has a length of more than 1600 μm but not more than 5000 μm , or more than 1600 μm but not more than 3000 μm .

The microneedle arrays shown in the (I-6) and (I-7) comprise the needles having a millimeter-order length as
20 above mentioned, but a micrometer-order fineness (the root diameter and the tip diameter of needle). The microneedle array of the present invention includes such arrays having the above needles having a millimeter-order length and a
25 micrometer-order fineness.

(I-8). The microneedle array according to any one of (I-1) to (I-7), wherein the proteoglycan content in the one or more microneedles is 20 to 100 wt.%.

(I-9). The microneedle array according to any one of (I-1) to (I-8), wherein the proteoglycan is chondroitin sulfate
30 proteoglycan.

(I-10). The microneedle array according to any one of (I-1) to (I-9), wherein the proteoglycan is derived from fish.

(I-11). The microneedle array according to (I-10), wherein
35 the fish is salmon, shark or jellyfish.

(I-12). The microneedle array according to any one of (I-1) to (I-11), wherein the one or more microneedles contain, in addition to the proteoglycan, a water-soluble polymer other than proteoglycan, or a cosmetically or pharmaceutically acceptable medicinal property.

(I-13). The microneedle array according to any one of (I-1) to (I-12), wherein the substrate has the same composition as the microneedles.

[0014]

10 (II) Method of Producing Microneedle Array

(II-1). A method of producing the microneedle array according to (I-1) or (I-11), the method comprising the steps of:

pouring an aqueous solution in which
15 proteoglycan for forming microneedles is dissolved into a mold in which the form of a microneedle array is recessed, so that a microneedle part and a substrate part are formed;

evaporating the moisture to dryness at room
20 temperature or by heating; and
removing the formed microneedle array from the mold.

[0015]

(II-2). A method of producing the microneedle array according to (I-1), the method comprising the steps of:

pouring an aqueous solution in which
proteoglycan for forming microneedles is dissolved into a mold in which the form of a microneedle is recessed;
evaporating the moisture to dryness at room
30 temperature or by heating;
laminating a substrate thereon and combining or bonding the bottom of the microneedles and the substrate;
and

removing the microneedles combined or bonded
35 with the substrate from the mold.

[0016]

(II-3). The method according to (II-1) or (II-2), wherein the aqueous solution in which proteoglycan for forming microneedles is dissolved contains the proteoglycan at a concentration of about 1 to 30 wt.%, preferably about 1 to 25 wt.%.

[Effect of the Invention]

[0017]

10 The present invention provides a microneedle array having one or more microneedles formed using proteoglycan as a base material. The microneedle array of the present invention comprises one or more microneedles that have the above excellent properties, i.e., (1) strength, (2) fineness and flexibility, and (3) solubility in the body. The microneedle array, which thus has sufficient properties for use as an external preparation, can adequately supply proteoglycan under the skin and underlying tissues.

20 [0018]

 Moreover, the microneedle array of the present invention is suitable for cosmetic or medical applications using the action of proteoglycan. Particularly, the microneedle array of the present invention is expected to an anti-aging activity such as a wrinkle-smoothing effect based on the epidermal cell growth-promoting activity of proteoglycan.

[Brief Description of the Drawings]

30 [0019]

 Fig. 1 shows a cross-sectional view of a mold (1) having microneedle-like shape recesses (11) and filled with a proteoglycan-containing aqueous solution (2).

 Fig. 2 shows a cross-sectional view of an example of the microneedle array of the present invention

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(Example 1). The microneedle array has a structure in which a plurality of solid konide-like shape microneedles (4) are formed on the surface of a substrate (3). In the drawing, Sign "a" denotes the length (height) of the microneedle formed on the substrate; Sign "b" denotes the root diameter of the microneedle; Sign "c" denotes the tip diameter of the microneedle; Sign "d" denotes the distance (pitch) between tips of adjacent microneedles formed on the substrate; and Sign "e" denotes the thickness of the substrate. Here, the "root diameter" of the microneedle indicates the diameter of the bottom of the microneedle attached to the surface of the substrate. More specifically, in the cross-sectional view shown in Fig. 2, the "root diameter" corresponds to the distance between the tangent points (6) of the microneedle relative to the substrate surface (5), which is regarded as the base line.

Fig. 3 shows a perspective view and an image of the microneedle array of the present invention used in Example 2. (A) illustrates a perspective view (a-1) and an image (a-2) of the microneedle array before use. (B) illustrates a perspective view (b-1) and an image (b-2) of the microneedle array after use. Sign "7" denotes a tape used to fix the microneedle array to the skin of the knee.

Fig. 4 shows the results of Example 2. (A) is an image of a site to which the microneedle array of the present invention containing a dye has been applied and then removed, and (B) is an image of the subcutaneous tissue of the site to which the microneedle array has been applied.

[Mode for Carrying Out the Invention]
[0020]

The microneedle array of the present invention comprises one or more microneedles formed on the surface of a substrate, the microneedles containing proteoglycan

as a base material. The following describes the microneedle array of the present invention in detail.

[0021]

Proteoglycan is a general term for molecules in which one or more glycosaminoglycans are covalently linked to a core protein. The type of proteoglycan used in the present invention is not particularly limited, and any of those belonging to chondroitin sulfate proteoglycan, dermatan sulfate proteoglycan, heparan sulfate proteoglycan, and keratan sulfate proteoglycan can be used. Specific examples of proteoglycan used in the present invention include aggrecan, versican, neurocan, brevican, decorin, biglycan, serglycin, perlecan, syndecan, glypican, lumican, keratocan, etc. Among these, it is preferable, in the present invention, to use chondroitin sulfate proteoglycan, and more preferably aggrecan, as a base material for forming microneedles.

[0022]

The source of proteoglycan used in the present invention is not particularly limited, and any of those derived from mammals such as humans, cows, and pigs; birds such as chickens; fish such as sharks, salmon and jellyfish; shellfish such as crabs and shrimps; and the like can be used. Among these sources, it is preferable to use proteoglycan derived from fish, more preferably salmon, and particularly preferably salmon nasal cartilage.

[0023]

Compared with proteoglycan derived from cows, pigs, and other higher animals, proteoglycan derived from shark cartilage has higher transparency, and is effective as a starting material for external skin preparations. For the purpose of reducing dark spots, wrinkles, and sagging, it is known to combine shark cartilage-derived proteoglycan with a melanogenesis inhibitor and a crude drug extract having an active oxygen eliminating effect

(Patent Document 5).

[0024]

The molecular weight of proteoglycan used in the present invention is not particularly limited, and is
5 suitably determined. Proteoglycan having a molecular weight of 80,000 to 3000,000 can generally be used without limitation; preferably used is proteoglycan having a molecular weight of 200,000 to 2500,000, and more preferably 300,000 to 800,000.

10 [0025]

In the present invention, the proportion of proteoglycan in the microneedles is not particularly limited as long as the microneedles contain proteoglycan as a base material. For example, the amount of
15 proteoglycan in the microneedles is generally 20 to 100 wt.%, preferably 50 to 100 wt.%, more preferably 70 to 100 wt.%, even more preferably 80 to 100 wt.%, and still more preferably 90 to 100 wt.%.

[0026]

20 More specifically, the microneedles of the present invention comprising proteoglycan as a base material may be composed only of proteoglycan, or may contain components other than proteoglycan in an amount up to 80 wt.%, and preferably 50 wt.%, as long as the
25 following properties of the microneedles composed of proteoglycan are not impaired:

(1) the strength to withstand insertion into the skin surface layer and/or stratum corneum,

(2) the fineness and flexibility to cause no
30 pain or bleeding in the skin surface layer and/or stratum corneum at the insertion site of the microneedles, and

(3) solubility or biodegradability in the body of the microneedle portions under the skin.

In the present invention, "comprising
35 proteoglycan as a base material" indicates the above

meaning.

[0027]

As components other than proteoglycan containable in the microneedles, water-soluble polymers other than proteoglycan can be used. Such water-soluble polymers may be those that can dissolve or degrade *in vivo*, and specific examples thereof include polysaccharides such as hyaluronic acid, chondroitin sulfate, glycogen, dextrin, dextran, dextran sulfate, hydroxypropyl methylcellulose, alginic acid, chitin, chitosan, and pullulan; proteins such as collagen, gelatin, and hydrolysates thereof; synthetic high polymers such as polyvinyl alcohol, polyvinyl pyrrolidone, polyacrylic acid, and carboxyvinyl polymer; and the like.

15 [0028]

When the microneedles contain a water-soluble polymer other than proteoglycan, the amount of the water-soluble polymer in the microneedles is generally 1 to 30 wt.%, preferably 1 to 25 wt.%, more preferably 1 to 20 wt.%, and further more preferably 1 to 10 wt.%.

20 [0029]

Moreover, in the present invention, the microneedles may contain cosmetically or pharmaceutically acceptable medicinal properties as the above other components.

25 [0030]

Among such medicinal properties, examples of cosmetically acceptable medicinal properties include whitening agents such as ascorbic acid, sodium ascorbyl phosphate, magnesium ascorbyl phosphate, ascorbyl palmitate, kojic acid, rucinol, tranexamic acid, licorice extract, and vitamin-A derivatives; anti-wrinkle agents such as retinol, retinoic acid, retinol acetate, and retinol palmitate; blood circulation accelerators such as tocopheryl acetate, capsaicin, and nonylic acid

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vanillylamide; dietary agents such as raspberry ketone, evening primrose extract, and seaweed extract; antimicrobial agents such as isopropyl methyl phenol, photosensitive pigments, and zinc oxide; antiphlogistics
5 such as salicylic acid; vitamins such as vitamin D₂, vitamin D₃, and vitamin K; and the like.
[0031]

Further, among the above medicinal properties, pharmaceutically acceptable medicinal properties may be,
10 other than the cosmetically acceptable medicinal properties described above, medicines used in the pharmaceutical field. Specific examples of medicines other than the aforementioned cosmetically available medicinal properties include antipyretic analgesic
15 antiphlogistics, such as ibuprofen, flurbiprofen, and ketoprofen; steroidal anti-inflammatory agents, such as hydrocortisone, triamcinolone, and prednisolone; vasodilators, such as diltiazem hydrochloride and isosorbide nitrate; antiarrhythmic agents, such as
20 procainamide hydrochloride and mexiletine hydrochloride; antihypertensives, such as clonidine hydrochloride, bunitrolol hydrochloride, and captopril; local anesthetics, such as tetracaine hydrochloride and propitocaine hydrochloride; hormone drugs, such as propylthiouracil,
25 estradiol, estriol, and progesterone; antihistamines, such as diphenhydramine hydrochloride and chlorpheniramine maleate; anesthetics, such as pentobarbital sodium; soporific analgesics, such as amobarbital and phenobarbital; antiepileptic agents, such as phenytoin
30 sodium; antipsychotic drugs, such as chlorpromazine hydrochloride, imipramine hydrochloride, chlordiazepoxide, and diazepam; skeletal muscle relaxants, such as suxamethonium hydrochloride and eperisone hydrochloride; autonomic drugs, such as neostigmine bromide and
35 bethanechol chloride; antiparkinson agents, such as

amantadine hydrochloride; diuretics, such as hydroflumethiazide, isosorbide, and furosemide; vasoconstrictors, such as phenylephrine hydrochloride; respiratory stimulants, such as lobeline hydrochloride, dimorpholamine, and naloxone hydrochloride; narcotics, such as morphine hydrochloride, cocaine hydrochloride, and pethidine hydrochloride; and the like. Furthermore, in the present invention, medicines to be added to the microneedles may be, other than those exemplified above, biologically active peptides and derivatives thereof, and fragments of nucleic acids, oligonucleotides, antigen proteins, bacteria, viruses, etc. Examples of such biologically active peptides and derivatives thereof include calcitonin, adrenocorticotrophic hormone, parathyroid hormone (PTH), hPTH (1→34), insulin, secretin, oxytocin, angiotensin, β -endorphin, glucagon, vasopressin, somatostatin, gastrin, luteinizing hormone-releasing hormone, enkephalin, neurotensin, atrial natriuretic peptide, growth hormone, growth hormone-releasing hormone, bradykinin, substance P, dynorphin, thyrotrophic hormone, prolactin, interferon, interleukin, G-CSF, glutathione peroxidase, superoxide dismutase, desmopressin, somatomedin, endothelin, salts thereof, etc. Examples of the above antigen protein include HBs surface antigen, HBe antigen, etc.

[0032]

The microneedle array of the present invention has a structure in which one or more microneedles are formed on the surface of a substrate. In the microneedle array of the present invention, the larger the number of microneedles, the higher the desired pharmacological activity. Accordingly, the substrate is desirably provided with a plurality of microneedles.

[0033]

The form of the microneedle may be suitably

determined so that it can be inserted into the skin and dissolve in the body (in the skin and underlying tissue), and so that pain and bleeding do not occur. For example, the microneedle preferably has a konide-like shape, a
5 circular truncated cone shape, or the like. The konide-like shape as used herein is a so-called volcano shape, that is, a circular truncated cone whose side surface is internally curved, as shown in Fig. 2. Moreover, the microneedle is preferably a solid needle, rather than a
10 hollow needle.

[0034]

A microneedle in a konide-like shape or a circular truncated cone shape preferably has a root diameter of about 120 to 400 μm , and more preferably about 150 to 300
15 μm , because a thin microneedle supplies a smaller amount of proteoglycan into the skin, and is easily broken when inserted into the skin, whereas a thick microneedle is hard to insert into the skin. The "root diameter" of the microneedle indicates the diameter of the bottom of the
20 microneedle attached to the surface of the substrate.

[0035]

A microneedle in a konide-like shape or a circular truncated cone shape preferably has a tip diameter of about 5 to 100 μm , and more preferably about
25 10 to 80 μm , because a thin (sharp) microneedle is easily broken when inserted into the skin, whereas a thick microneedle is hard to insert into the skin, thereby causing pain.

[0036]

30 A microneedle in a konide-like shape or a circular truncated cone shape preferably has a length of about 100 μm or more, preferably about 150 μm or more, and more preferably about 200 μm or more, because a short microneedle is shallowly inserted into the skin and
35 therefore makes it difficult to supply proteoglycan. The

upper limit of the length of the microneedle is not particularly limited as long as the microneedle is not broken when inserted into the skin. The upper limit of the length is generally about 5000 μm or less, preferably about 3000 μm or less, and more preferably about 1600 μm or less. Specifically, the length of the microneedle is, for example, about 100 to 5000 μm , preferably about 100 to 3000 μm . The microneedle is included the microneedle having a length of about 100 to 1600 μm , preferably about 150 to 1200 μm , or more preferably about 150 to 1000 μm , and the microneedle having a length of more than about 1000 μm but not more than 5000 μm , preferably more than about 1600 μm but not more than 5000 μm , or more preferably more than about 1600 μm but not more than 3000 μm .

[0037]

In the microneedle array, as for the distance between one microneedle and an adjacent microneedle, a shorter distance makes it difficult to insert the microneedles into the skin, while a longer distance results in a smaller number of microneedles per unit area, causing an insufficient supply of proteoglycan into the skin. From this viewpoint, the space between the microneedles arranged in the microneedle array is preferably such that the distance between the tip of one microneedle and the tip of an adjacent microneedle (this distance is referred to as the "pitch" in the present invention) is about 100 to 1800 μm , and preferably about 150 to 1200 μm .

[0038]

The number of microneedles per unit area of the substrate surface of the microneedle array is suitably determined depending on the pitch described above, and other factors. For example, the number of microneedles per cm^2 of the substrate surface of the microneedle array

is generally about 50 to 300, preferably about 100 to 200, and more preferably about 120 to 160. Although the arrangement of the plurality of microneedles in the microneedle array is not particularly limited, they are
5 preferably arranged in a grid pattern.

[0039]

In the microneedle array of the present invention, the substrate is not particularly limited, as long as it is a film or sheet on which the microneedles
10 can be attached, held, or formed. The substrate may be a film or sheet having the same composition as the microneedles, or it may be a film or sheet having a different composition from the microneedles. Specific examples of films or sheets having a different composition
15 from the microneedles include films or sheets made of polymethyl methacrylate, cellulose acetate, ethyl cellulose, polyethylene resin, polypropylene resin, ethylene-propylene copolymer, ethylene-vinyl acetate copolymer, vinyl chloride-based resin, vinylidene chloride
20 resin, vinyl acetate-vinyl chloride copolymer, polyamide-based resin, polyester resin, acrylonitrile-butadiene-styrene copolymer, styrene-isoprene-styrene copolymer, styrene-ethylene-butylene-styrene copolymer, urethane resin, silicon resin, aluminum, etc. In terms of the ease
25 of production, the substrate is preferably formed of a film or sheet having the same composition as the microneedles. In this case, the substrate can be integrally formed with the microneedles.

[0040]

30 The substrate is not particularly limited; however, it is preferable that the microneedles can be attached or held on the surface of the substrate, and that the substrate has a thickness that allows the microneedles to be inserted into the surface layer and/or stratum
35 corneum. Although the thickness of the substrate may be

generally determined within the range of about 50 μm or more, for example, the thickness is preferably about 50 to 500 μm , and more preferably about 80 to 300 μm , further more preferably about 100 to 200 μm .

5 [0041]

The method of producing the microneedle array of the present invention is not particularly limited, and the microneedle array can be produced by a known method.

Examples of the microneedle array production method of the present invention include methods (i) and (ii) described below.

[0042]

(i) An aqueous solution in which components for forming the microneedles are dissolved is poured into a mold in which the form of a microneedle array is recessed, so that a microneedle part and a substrate part are formed. The moisture is evaporated, and the resultant is dried at room temperature or by heating. Then, the formed microneedle array is removed from the mold. According to this method, a microneedle array whose microneedles and substrate have the same composition can be produced.

[0043]

(ii) An aqueous solution in which components for forming the microneedles are dissolved is poured into a mold in which the form of a microneedle array is recessed. The moisture is evaporated, and the resultant is dried at room temperature or by heating. Subsequently, a substrate is laminated on the microneedles formed above, and the bottom of the microneedles and the substrate are bonded or combined with each other. The microneedles are then removed, together with the substrate, from the mold. According to this method, a microneedle array whose microneedles and substrate have different compositions can be produced.

35 [0044]

In the above methods (i) and (ii), the aqueous solution in which components for forming the microneedles are dissolved is not particularly limited as long as it has a concentration sufficient enough to enable
5 proteoglycan to dissolve. For example, an aqueous solution having a proteoglycan concentration of about 1 to 30 wt.%, preferably about 1 to 25 wt.% can be used.
[0045]

The microneedle array of the present invention
10 is used by applying it to the skin so that the microneedles are inserted into the skin surface layer and/or stratum corneum. More specifically, the microneedle array of the present invention is attached to the skin so that the microneedles are inserted into the
15 skin surface layer and/or stratum corneum, and the microneedle array is left in this state. Thereby, proteoglycan in the microneedles dissolves in the body because of the subcutaneous temperature and moisture and is eluted under the skin and underlying tissues to exert
20 useful pharmacological activity based on the proteoglycan. When microneedles contain water-soluble polymers or cosmetically or pharmaceutically acceptable medicinal properties, as described above, these components in the microneedles are eluted into the skin, together with the
25 proteoglycan, so that useful pharmacological activity based on the proteoglycan and these components is exerted under the skin.
[0046]

In order to more effectively achieve the
30 pharmacological activity of the proteoglycan, etc., it is preferable that the microneedles inserted into the skin surface layer and/or stratum corneum are held as they are for generally about 30 minutes or more, preferably 30 to 300 minutes, and preferably about 60 to 180 minutes. This
35 allows the proteoglycan forming the microneedles to

sufficiently dissolve and elute under the skin.

[0047]

As described above, the microneedle array of the present invention can supply at least proteoglycan into
5 the skin and underlying tissues, and is thus used for cosmetic or medical applications that take advantage of the proteoglycan activity.

[0048]

For example, proteoglycan is known to exhibit
10 promotion of epidermal cell growth (Non-patent Document 1). Hence, the microneedle array of the present invention can be used for cosmetic purposes, such as skin whitening, moisturizing, and antiaging based on the proteoglycan action.

15 [0049]

Proteoglycan is also known to exhibit actions of immunostimulation, anti-inflammation, etc. Accordingly, the microneedle array of the present invention is also effective for medical purposes, such as skin tissue
20 immunological adjuvants, antiphlogistics for inflammation of skin tissue, etc.

[Examples]

[0050]

25 The present invention is described in detail below with reference to Examples. However, the present invention should not be interpreted as being limited to the Examples. The proteoglycan used in the following Examples was chondroitin sulfate proteoglycan derived from
30 salmon nasal cartilage (eluted from salmon nasal cartilage using acetic acid; produced by Kakuhiko Corporation, Japan).

[0051]

Example 1 Production of Microneedle Array

35 An aqueous solution containing 20 wt.% of

proteoglycan was poured into a mold in which the form of a microneedle array was recessed. Fig. 1 shows a cross-sectional view of the mold (1) in which the form of a microneedle array was recessed and the 20 wt.%
5 proteoglycan-containing aqueous solution (2) was poured. More specifically, Sign 1 in Fig. 1 indicates a mold in which concave portions (11) for forming microneedles are formed in such a manner that a pattern of microneedles in a predetermined shape is formed on the surface of a
10 photopolymer by a lithography technique (light irradiation), followed by electroforming to transfer the pattern of the microneedles in the predetermined shape. The concave portions (11) for forming microneedles shown in Fig. 1 each have a concave portion in the form of a
15 konide-like shape having an open end diameter (corresponding to the root diameter of the microneedle) of 200 μm , a bottom diameter (corresponding to the tip diameter of the microneedle) of 40 μm , and a depth (corresponding to the length of the microneedle) of 800 μm .
20 The concave portions are arranged in a grid pattern at intervals of 800 μm on the photopolymer, and 144 concave portions are formed per cm^2 .

[0052]

Sign 2 in Fig. 1 indicates an aqueous solution
25 layer formed by pouring the 20 wt.% proteoglycan-containing aqueous solution into the mold (1).

[0053]

The 20 wt.% proteoglycan-containing aqueous solution poured into the mold (1) was dried in this state
30 in an oven at 35°C for 5 hours to evaporate the moisture. The dried product formed on the mold (1) was then removed from the mold (1). The microneedle array of the present invention shown in Fig. 2 was obtained in this manner. In the microneedle array, a number of fine solid konide-like
35 shape microneedles (4) are formed on the surface of the

substrate (3) by pouring the 20 wt.% proteoglycan-containing aqueous solution into the concave portions (11) for forming microneedles, followed by drying. The substrate (3) and microneedles (4) are both composed of proteoglycan. The produced microneedle array is in the shape of an ellipse with a size of 6 mm (shorter axis) x 10 mm (longer axis), depending on the size of the substrate (3).

[0054]

10 The microneedles (4) are each in a solid konide-like shape with a length (Sign a) of 800 μm , a root diameter (Sign b) of 200 μm , and a tip diameter (Sign c) of 40 μm ; and the distance (Sign d) between the tip of one microneedle (4) and the tip of another adjacent
15 microneedle (4) is 800 μm . The microneedles (4) are arranged on the substrate in a grid pattern at the above intervals, and about 144 microneedles are formed per cm^2 . The thickness (Sign e) of the substrate (3) is 200 μm .

[0055]

20 The microneedles of the thus-produced microneedle array were fine needles, had good strength and flexibility, and could be inserted into the skin surface layer and/or stratum corneum with almost no pain, as described above. Moreover, the microneedles, which were
25 composed only of proteoglycan except for residual moisture, exhibited excellent solubility under the skin by maintaining them under the skin for about 90 minutes after subcutaneous insertion.

[0056]

30 Additionally, the microneedle array having microneedles composed of 100% proteoglycan except for residual moisture, as described above, is expected to be effective for cosmetic or medical purposes based on proteoglycan activity. The microneedle array is also
35 expected to be effective for cosmetic purposes, such as

wrinkle smoothing, based on proteoglycan activity.

[0057]

Although the microneedle array produced in Example 1 comprises konide-like shape microneedles, a
5 microneedle array comprising circular truncated cone-
shape microneedles can be produced by using concave
portions (11) for forming microneedles in the form of a
circular truncated cone.

10 [0058]

Example 2 Usability Assessment of Microneedle Array

Using an aqueous solution containing 20 wt.% of
proteoglycan and 10 wt.% of Evans blue dye, a microneedle
array in the shape of an ellipse with a size of 8 mm
15 (shorter axis) x 10 mm (longer axis) (length of
microneedle: 800 μ m) was produced in the same manner as in
Example 1. The produced microneedle array was cut into
pieces about 7 mm in size, and they were applied to the
knees of rats to examine how the Evans blue dye penetrated
20 into the surrounding tissue of the knees.

[0059]

(1) Test Animals

SD rats (CrI:CD, male, 5 weeks old, 164 to 183
g; Charles River Laboratories Japan, Inc.) were kept
25 overnight (lighting hours: 12 hours, non-lighting hours:
12 hours) under the conditions in which the temperature
was $23 \pm 2^{\circ}\text{C}$, and the humidity was $60 \pm 10\%$. They were
then subjected to the following experiments. The test
animals were treated in accordance with the guidelines for
30 animal experiments of Otsuka Pharmaceutical Co., Ltd., and
they were allowed to freely take food (MF: Oriental Yeast
Co., Ltd.) and water (tap water).

[0060]

(2) Test Method

35 The hair of both knees of the individual test

animals (n=5) was shaved with an electric shaver and then removed with a depilatory cream. The microneedle arrays (about 7 mm × 7 mm) produced above were applied to the dehaired skin of the knees. More specifically, the
5 microneedle array was pressed and applied to the skin of the knee so that the microneedles were inserted into the skin, and the microneedle array was press-fixed to the skin by taping. The microneedle arrays were applied to the test animals in this manner, and the test animals were
10 secured in Bollman restraining cages to prevent movement.
[0061]

After two hours from the application of the microneedle arrays, the test animals were released from the cages, and euthanized under ether anesthesia.
15 Thereafter, the microneedle arrays were removed from the skin, and the form of the microneedles, the surface and subcutaneous tissue of the skin of the knees to which the microneedle arrays were applied were observed to evaluate the solubility of the microneedles under the skin and the
20 penetrance of Evans blue dye staining in the skin surface and subcutaneous tissue.
[0062]

(3) Test Results

(3-1) Form of Microneedle

25 The 800-μm microneedle portions of the applied microneedle array all disappeared. This confirmed that the microneedles inserted into the skin subcutaneously dissolved because of the body temperature and the surrounding moisture.

30 [0063]

(3-2) Observation of Microneedle Array-Applied Site (Knee)

In all the test animals (n=5), the surface and subcutaneous tissue of the skin of the microneedle array-
35 applied site were stained by the Evans blue dye, while the

muscular layer was not stained. This confirmed that the components (proteoglycan and Evans blue dye) eluted by dissolution of the microneedles reached under the skin. Additionally, no abnormal findings (e.g., bleeding) were
5 observed in the microneedle array-applied sites (skin, subcutaneous tissue, and muscular layer) of the test animals.

[Document Name] Claims

1. A microneedle array comprising one or more microneedles formed on the surface of a substrate, the
5 microneedles comprising proteoglycan as a base material.
2. The microneedle array according to claim 1, wherein each of the microneedles has a konide-like shape or a circular truncated cone shape.
10
3. The microneedle array according to claim 1 or 2, wherein each of the microneedles is a solid needle.
4. The microneedle array according to claim 2 or 3,
15 wherein each of the microneedles has a root diameter of 120 to 400 μm , a tip diameter of 5 to 100 μm , and a length of 100 to 5000 μm , and the distance between tips of adjacent microneedles is 100 to 1800 μm .
- 20 5. The microneedle array according to any one of claims 1 to 4, wherein the proteoglycan content in the one or more microneedles is 20 to 100 wt.%.
6. The microneedle array according to any one of
25 claims 1 to 5, wherein the proteoglycan is chondroitin sulfate proteoglycan.
7. The microneedle array according to any one of
30 claims 1 to 6, wherein the proteoglycan is derived from fish.
8. The microneedle array according to claim 7, wherein the fish is salmon, shark or jellyfish.
- 35 9. The microneedle array according to any one of

claims 1 to 8, wherein the one or more microneedles contain, in addition to the proteoglycan, a water-soluble polymer other than proteoglycan, or a cosmetically or pharmaceutically acceptable medicinal property.

5

10. The microneedle array according to any one of claims 1 to 8, wherein the substrate has the same composition as the microneedles.

10 11. A method of producing the microneedle array according to claim 1 or 10, the method comprising the steps of (1) to (3) or (1') to (4'):

(1) pouring an aqueous solution in which proteoglycan for forming microneedles is dissolved into a
15 mold in which the form of a microneedle array is recessed, so that a microneedle part and a substrate part are formed;

(2) evaporating the moisture to dryness at room temperature or by heating, and

20 (3) removing the formed microneedle array from the mold; or

(1') pouring an aqueous solution in which proteoglycan for forming microneedles is dissolved into a mold in which the form of a microneedle is recessed;

25 (2') evaporating the moisture to dryness at room temperature or by heating;

(3') laminating a substrate thereon and combining or bonding the bottom of the microneedles and the substrate, and

30 (4') removing the microneedles combined or bonded with the substrate from the mold.

12. The method according to claim 11, wherein the aqueous solution in which proteoglycan for forming
35 microneedles is dissolved contains the proteoglycan at a

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concentration of about 1 to 30 wt.%.