

[Document Name] Description

[Title of Invention] ANTISENSE NUCLEIC ACID THAT INDUCES SKIPPING OF EXON 50

[Technical Field]

[0001]

The present invention relates to an antisense oligomer which induces skipping of exon 50 in the human dystrophin gene, and a pharmaceutical composition comprising the antisense oligomer.

[Background Art]

[0002]

Duchenne muscular dystrophy (DMD) is the most frequent and severe form of hereditary progressive muscular atrophy that is developed in one in about 3,500 newborn boys. Although the motor functions in DMD patients are rarely different from healthy humans in infancy and childhood, their muscle weakness is observed in children from around 4 to 5 years old. Then, muscle weakness in DMD patients progresses to the loss of ambulation by about 12 years old and death due to cardiac or respiratory insufficiency in the twenties. At present, there is no sufficient therapy for DMD, and it has been strongly desired to develop an effective therapeutic agent.

[0003]

DMD is known to be caused by a mutation in the dystrophin gene. The dystrophin gene is located on X chromosome and is a huge gene consisting of 2.2 million DNA base pairs. DNA is transcribed into mRNA precursors, and introns are removed by splicing to synthesize mRNA of 11,058 bases corresponding to a translated region, in which 79 exons are joined together. This mRNA is translated into 3,685 amino acids to produce the dystrophin protein. The dystrophin protein is

associated with the maintenance of membrane stability in muscle cells and necessary to make muscle cells less fragile. The dystrophin gene from patients with DMD contains a mutation and hence, the dystrophin protein, which is functional in muscle cells, is rarely expressed. Therefore, the structure of muscle cells cannot be maintained in the body of the patients with DMD, leading to a large influx of calcium ions into muscle cells. Consequently, an inflammation-like response occurs to promote fibrosis to make the regeneration of muscle cells difficult.

[0004]

Becker muscular dystrophy (BMD) is also caused by a mutation in the dystrophin gene. The symptoms involve muscle weakness accompanied by atrophy of muscle but are typically mild and slow in the progress of muscle weakness, when compared to DMD. In many cases, its onset is in adulthood. Differences in clinical symptoms between DMD and BMD are considered to reside in whether the reading frame for amino acids on the translation of dystrophin mRNA into the dystrophin protein is disrupted by the mutation or not (Non Patent Literature 1). More specifically, in DMD, the presence of mutation shifts the amino acid reading frame and thereby the functional dystrophin protein is rarely expressed, whereas in BMD the dystrophin protein that functions, though imperfectly, is produced because the amino acid reading frame is preserved, while a part of the exons are deleted by the mutation.

[0005]

Exon skipping is expected to serve as a method for treating DMD. This method involves modifying splicing to restore the amino acid reading frame of dystrophin mRNA and induce expression of the dystrophin protein having the function partially restored (Non Patent Literature 2). The amino acid sequence part, which is a target of exon skipping, will be lost. For this reason, the dystrophin protein expressed by this treatment becomes shorter than normal one but since the amino acid reading frame is maintained, the function to stabilize muscle cells is partially retained. Consequently, it is expected that exon skipping will lead DMD to the similar

symptoms to that of BMD which is milder. The exon skipping approach has passed the animal tests using mice or dogs and now is currently assessed in clinical trials on human DMD patients.

[0006]

The skipping of an exon can be induced by binding of antisense nucleic acids targeting either 5' or 3' splice site or both sites, or exon-internal sites. An exon will be included in the mRNA only when both splice sites thereof are recognized by the spliceosome complex. Thus, exon skipping can be induced by targeting the splice sites with antisense nucleic acids. Furthermore, the binding of an SR protein to an exonic splicing enhancer (ESE) is considered necessary for an exon to be recognized by the splicing mechanism. Accordingly, exon skipping can also be induced by targeting ESE.

[0007]

Since a mutation of the dystrophin gene may vary depending on DMD patients, antisense nucleic acids need to be designed based on the site or type of respective genetic mutation. In the past, antisense nucleic acids that induce exon skipping for all 79 exons were produced by Steve Wilton, et al., University of Western Australia (Non Patent Literature 3), and the antisense nucleic acids which induce exon skipping for 39 exons were produced by Annemieke Aartsma-Rus, et al., Netherlands (Non Patent Literature 4).

[0008]

It is considered that approximately 4% of all DMD patients may be treated by skipping the 50th exon (hereinafter referred to as "exon 50") (Non Patent Literature 5). In recent years, a plurality of research organizations including the applicant reported on the studies where exon 50 in the dystrophin gene was targeted for exon skipping (Patent Literatures 1 to 6 and Non Patent Literature 6).

[Citation List]

[Patent Literature]

[0009]

[Patent Literature 1] International Publication WO2013/100190

[Patent Literature 2] International Publication WO2004/048570

[Patent Literature 3] International Publication WO2006/000057

[Patent Literature 4] International Publication WO2010/050802

[Patent Literature 5] International Publication WO2010/048586

[Patent Literature 6] International Publication WO2011/057350

[0010]

[Non Patent Literature 1] Monaco A. P. et al., Genomics 2:90-95 (1988)

[Non Patent Literature 2] Matsuo M., Brain and Development 18:167-172 (1996)

[Non Patent Literature 3] Wilton S. D. et al., Molecular Therapy 15:1288-96 (2007)

[Non Patent Literature 4] Annemieke Aartsma-Rus et al., Neuromuscular Disorders 12:S71-S77 (2002)

[Non Patent Literature 5] Bladen C. L. et al., Human Mutation 36:395-402 (2015)

[Non Patent Literature 6] Bo Wu et al., PLoSOne 6(5):e19906 (2011)

[Summary of Invention]

[Technical Problem]

[0011]

Under the foregoing circumstances, novel antisense oligomers that induce exon 50 skipping in the dystrophin gene with high efficiency have been desired. Also, antisense oligomers that have excellent physical properties (*e.g.*, solubility) as medicaments while maintaining an activity to induce exon 50 skipping in the dystrophin gene with high efficiency have been desired.

[Solution to Problem]

[0012]

As a result of detailed studies of the technical contents of the above documents and the structure of the dystrophin gene, the present inventors have found that exon 50 skipping in the human dystrophin gene is induced with high efficiency by administering the antisense oligomer having a base sequence represented by any of SEQ ID NOs: 3 to 5. The present inventors have also found that the antisense oligomer has excellent solubility while inducing exon 50 skipping in the human dystrophin gene with high efficiency. Based on this finding, the present inventors have accomplished the present invention.

[0013]

That is, the present invention is as follows.

[1]

An antisense oligomer which is selected from the group consisting of (a) to (d) below:

- (a) an antisense oligomer comprising a base sequence of any of SEQ ID NOs: 3 to 5;
 - (b) an antisense oligomer which comprises a base sequence having deletion, substitution, insertion and/or addition of 1 to 5 base(s) in the base sequence of any of SEQ ID NOs: 3 to 5, and has an activity to induce skipping of exon 50 in the human dystrophin gene;
 - (c) an antisense oligomer which comprises a base sequence having at least 80% sequence identity to a base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene; and
 - (d) an antisense oligomer that hybridizes under stringent conditions to an oligonucleotide consisting of a base sequence complementary to the base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene,
- or a pharmaceutically acceptable salt or hydrate thereof.

[2]

An antisense oligomer which is selected from the group consisting of (e) to (h) below:

- (e) an antisense oligomer which consists of a base sequence of any of SEQ ID NOs: 3 to 5;
 - (f) an antisense oligomer which consists of a base sequence having deletion and/or substitution of 1 to 5 base(s) in the base sequence of any of SEQ ID NOs: 3 to 5, and has an activity to induce skipping of exon 50 in the human dystrophin gene;
 - (g) an antisense oligomer which consists of a base sequence having at least 80% sequence identity to a base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene; and
 - (h) an antisense oligomer that hybridizes under high stringent conditions to an oligonucleotide consisting of a base sequence complementary to the base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene,
- or a pharmaceutically acceptable salt or hydrate thereof.

[3]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to [1] or [2] above, wherein

the antisense oligomer is

an antisense oligomer which has a nucleotide sequence having at least 90% sequence identity to a base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene.

[4]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any of [1] to [3] above, wherein the antisense oligomer is an oligonucleotide.

[5]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to [4] above, wherein the sugar moiety and/or the phosphate bond moiety of at least one nucleotide constituting the oligonucleotide are/is modified.

[6]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to [4] or [5] above, wherein the sugar moiety of at least one nucleotide constituting the oligonucleotide is a ribose in which the 2'-OH group is replaced by any one selected from the group consisting of OR, R, R'OR, SH, SR, NH₂, NHR, NR₂, N₃, CN, F, Cl, Br and I (wherein R is an alkyl or an aryl and R' is an alkylene).

[7]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any of [4] to [6] above, wherein the phosphate bond moiety of at least one nucleotide constituting the oligonucleotide is any one selected from the group consisting of a phosphorothioate bond, a phosphorodithioate bond, an alkylphosphonate bond, a phosphoramidate bond and a boranophosphate bond.

[8]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any of [1] to [3] above, wherein the antisense oligomer is a morpholino oligomer.

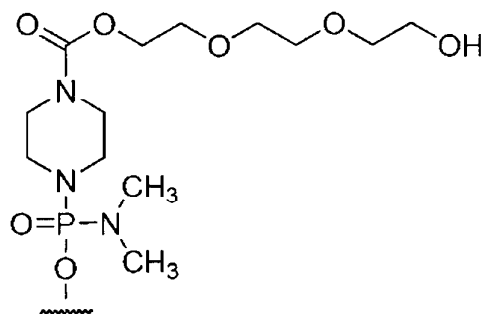
[9]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to [8] above, wherein the antisense oligomer is a phosphorodiamidate morpholino oligomer.

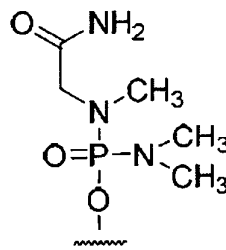
[10]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to [8] or [9] above, wherein the 5' end is any one of chemical formulae (1) to (3) below:

[Formula 1]



(1)



(2)



(3)

[11]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any of [1] to [10] above, wherein the length of the antisense oligomer is 19 or 20 bases.

[12]

A pharmaceutical composition for the treatment of muscular dystrophy, comprising the antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any of [1] to [11] above.

[13]

The pharmaceutical composition according to [12] above, further comprising a pharmaceutically acceptable carrier.

[14]

The pharmaceutical composition according to [12] or [13] above for being administered to a patient with muscular dystrophy, wherein the patient is a patient having a mutation that is amenable to exon 50 skipping in the dystrophin gene.

[15]

The pharmaceutical composition according to [14] above, wherein the patient has the dystrophin gene that has at least a frameshift mutation caused by deletion of

an exon in the vicinity of exon 50 and in which the amino acid reading frame is corrected by exon 50 skipping.

[16]

The pharmaceutical composition according to [14] or [15] above, wherein the patient has a frameshift mutation caused by deletions of exons 51, 51-53, 51-55, or 51-57 in the dystrophin gene.

[17]

The pharmaceutical composition according to any of [14] to [16] above, wherein the patient is a human.

[18]

Use of the antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any of [1] to [11] above in the manufacture of a medicament for the treatment of muscular dystrophy.

[19]

A method for treatment of muscular dystrophy, which comprises administering to a patient with muscular dystrophy an effective amount of the antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any of [1] to [11] above, or the pharmaceutical composition according to any of [12] to [16] above.

[20]

The method for treatment according to [19] above, wherein the patient is a human.

[21]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any of [1] to [11] above, or the pharmaceutical composition according to any of [12] to [16] above for use in the treatment of muscular dystrophy.

[22]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof, or the pharmaceutical composition according to [21] above, wherein in the treatment, a patient with muscular dystrophy is a human.

[Effects of Invention]

[0014]

The present invention can provide an antisense oligomer that induces exon 50 skipping in the human dystrophin gene with high efficiency. The present invention can provide an antisense oligomer that has excellent solubility while maintaining an activity to induce exon 50 skipping in the human dystrophin gene with high efficiency.

[Brief Description of Drawings]

[0015]

[Figure 1] Figure 1 shows the efficiency of exon 50 skipping in the human dystrophin gene by antisense oligomers of PMO Nos. 1 and 2 in human rhabdomyosarcoma cells (RD cells).

[Figure 2] Figure 2 shows the efficiency of exon 50 skipping in the human dystrophin gene by antisense oligomers of PMO Nos. 1, 3, and 4 in RD cells.

[Figure 3] Figure 3 shows the efficiency of exon 50 skipping in the human dystrophin gene by antisense oligomers of PMO Nos. 1, 5, 6 and 7 in RD cells.

[Description of Embodiments]

[0016]

Hereinafter, the present invention is described in detail. The embodiments described below are intended to be presented by way of example merely to describe the invention but not intended to limit the present invention only to the following embodiments. The present invention may be implemented in various ways without departing from the gist of the invention.

[0017]

1. Antisense oligomer

The present invention provides an antisense oligomer (hereinafter referred to as the "antisense oligomer of the present invention") which causes skipping of exon 50 in the human dystrophin gene with high efficiency.

[0018]

[Exon 50 in human dystrophin gene]

In the present invention, the term "gene" includes a genomic gene and also includes cDNA, mRNA precursor and mRNA. Preferably, the gene is mRNA precursor, i.e., pre-mRNA.

In the human genome, the human dystrophin gene locates at locus Xp21.2. The human dystrophin gene has a size of 2.2 million base pairs and is the largest gene among known human genes. However, the coding regions of the human dystrophin gene are only 14 kb, distributed as 79 exons throughout the human dystrophin gene (Roberts, RG, et al., Genomics, 16: 536-538 (1993); and Koenig, M., et al., Cell 53 219-228, 1988). The pre-mRNA, which is the transcript of the human dystrophin gene, undergoes splicing to generate mature mRNA of 14 kb. The base sequence of human wild-type dystrophin gene is known (GenBank Accession No. NM_004006).

A base sequence including exon 50 and a sequence in the vicinity of 5' end of intron 50 in the human wild-type dystrophin gene is represented by SEQ ID NO: 1.

[0019]

[Antisense oligomer]

The antisense oligomer of the present invention is designed to cause skipping of exon 50 in the human dystrophin gene, thereby modifying the protein encoded by DMD type dystrophin gene into BMD type dystrophin protein. Accordingly, exon 50 in the dystrophin gene that is a target of exon skipping by the antisense oligomer includes both wild type and mutant types.

[0020]

The antisense oligomer of the present invention is specifically an antisense oligomer which is selected from the group consisting of (a) to (d) below.

- (a) an antisense oligomer comprising a base sequence of any of SEQ ID NOs: 3 to 5;
- (b) an antisense oligomer which comprises a base sequence having deletion, substitution, insertion and/or addition of 1 to 5, 1 to 4, 1 to 3, 1 to 2, or 1 base(s) in the base sequence of any of SEQ ID NOs: 3 to 5, and has an activity to induce skipping of exon 50 in the human dystrophin gene;
- (c) an antisense oligomer which comprises a base sequence having at least 80%, at least 84%, at least 85%, at least 89%, at least 90%, at least 94%, or at least 95% sequence identity to a base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene; and
- (d) an antisense oligomer that hybridizes under stringent conditions to an oligonucleotide consisting of a base sequence complementary to the base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene.

[0021]

As another embodiment, the antisense oligomer of the present invention is specifically an antisense oligomer which is selected from the group consisting of (e) to (h) below.

- (e) an antisense oligomer which consists of a base sequence of any of SEQ ID NOs: 3 to 5;
- (f) an antisense oligomer which consists of a base sequence having deletion and/or substitution of 1 to 5, 1 to 4, 1 to 3, 1 to 2, or 1 base(s) in the base sequence of any of SEQ ID NOs: 3 to 5, and has an activity to induce skipping of exon 50 in the human dystrophin gene;
- (g) an antisense oligomer which consists of a base sequence having at least 80%, at least 84%, at least 85%, at least 89%, at least 90%, at least 94%, or at least 95%

sequence identity to a base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene; and

(h) an antisense oligomer that hybridizes under high stringent conditions to an oligonucleotide consisting of a base sequence complementary to the base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene.

[0022]

The antisense oligomers of (b) to (d) and the antisense oligomers of (f) to (h) are mutants of the antisense oligomer of (a) and the antisense oligomer of (e), respectively, in particular and are intended to correspond to mutations (*e.g.*, polymorphism) of the dystrophin gene of the patients.

[0023]

As used herein, the term "antisense oligomer that hybridizes under stringent conditions" refers to, for example, an antisense oligomer obtained by colony hybridization, plaque hybridization, Southern hybridization or the like, using as a probe all or part of an oligonucleotide consisting of a base sequence complementary to the base sequence of, *e.g.*, any of SEQ ID NOs: 3 to 5. The hybridization method which may be used includes methods described in, for example, "Sambrook & Russell, Molecular Cloning: A Laboratory Manual Vol. 3, Cold Spring Harbor, Laboratory Press 2001," "Ausubel, Current Protocols in Molecular Biology, John Wiley & Sons 1987-1997," etc.

[0024]

As used herein, the term "stringent conditions" may be any of low stringent conditions, moderate stringent conditions or high stringent conditions. The term "low stringent condition" is, for example, 5 × SSC, 5 × Denhardt's solution, 0.5% SDS, 50% formamide at 32°C. The term "moderate stringent condition" is, for example, 5 × SSC, 5 × Denhardt's solution, 0.5% SDS, 50% formamide at 42°C, or 5 × SSC, 1% SDS, 50 mM Tris-HCl (pH 7.5), 50% formamide at 42°C. The term "high stringent

condition" is, for example, (1) $5 \times \text{SSC}$, $5 \times \text{Denhardt's solution}$, $0.5\% \text{ SDS}$, $50\% \text{ formamide}$ at 50°C , (2) $0.2 \times \text{SSC}$, $0.1\% \text{ SDS}$ at 60°C , (3) $0.2 \times \text{SSC}$, $0.1\% \text{ SDS}$ at 62°C , (4) $0.2 \times \text{SSC}$, $0.1\% \text{ SDS}$ at 65°C , or (5) $0.1 \times \text{SSC}$, $0.1\% \text{ SDS}$ at 65°C , but is not limited thereto. Under these conditions, antisense oligomers with higher sequence identity are expected to be obtained efficiently at higher temperatures. Multiple factors are involved in hybridization stringency including temperature, probe concentration, probe length, ionic strength, time, salt concentration and others, and those skilled in the art may appropriately select these factors to achieve similar stringency. Herein, the term "sequence identity" refers to identity over the whole ranges of base sequences to be compared between a pair of two certain nucleic acids and is indicated by the ratio (%) of matched bases in the optimum alignment of the base sequences produced using a mathematical algorithm known in the technical field of the present invention. For example, an antisense oligomer consisting of a base sequence having at least "80% sequence identity" to an antisense oligomer consisting of a 20-base sequence means an antisense oligomer having 16 or more bases identical to the 20-base antisense oligomer.

[0025]

When commercially available kits are used for hybridization, for example, an Alkphos Direct Labelling and Detection System (GE Healthcare) may be used. In this case, according to the attached protocol to the kit, after incubation with a labeled probe overnight, the membrane is washed with a primary wash buffer containing $0.1\% \text{ (w/v) SDS}$ at 55°C , thereby enabling to detect hybridized antisense oligomer. Alternatively, when the probe is labeled with digoxigenin (DIG) using a commercially available reagent (*e.g.*, a PCR Labelling Mix (Roche Diagnostics), etc.) in producing a probe based on all or part of the complementary sequence to the base sequence of any of SEQ ID NOs: 3 to 5, hybridization can be detected with a DIG Nucleic Acid Detection Kit (Roche Diagnostics).

[0026]

In addition to the antisense oligomer described above, other antisense oligomer that can hybridize include antisense oligomers having 90% or higher, 91% or higher, 92% or higher, 93% or higher, 94% or higher, 95% or higher, 96% or higher, 97% or higher, 98% or higher, 99% or higher, 99.1% or higher, 99.2% or higher, 99.3% or higher, 99.4% or higher, 99.5% or higher, 99.6% or higher, 99.7% or higher, 99.8% or higher, and 99.9% or higher sequence identity to the base sequence of any of SEQ ID NOs: 3 to 5, as calculated by homology search software such as FASTA and BLAST using the default parameters.

[0027]

The sequence identity may be determined using FASTA (Science 227 (4693): 1435-1441, (1985)) or algorithm BLAST (Basic Local Alignment Search Tool) by Karlin and Altschul (Proc. Natl. Acad. Sci. USA 87:2264-2268, 1990; Proc. Natl. Acad. Sci. USA 90: 5873, 1993). Programs called blastn, blastx, tblastn and tblastx based on the BLAST algorithm have been developed (Altschul SF, et al: J. Mol. Biol. 215: 403, 1990). When a base sequence is analyzed using blastn, the parameters are, for example, score = 100 and wordlength = 12. When BLAST and Gapped BLAST programs are used, the default parameters for each program are employed.

[0028]

The term "induce (enable) skipping of the exon 50 in the human dystrophin gene" is intended to mean that by binding of the antisense oligomer of the present invention to the site corresponding to exon 50 and/or its adjacent intron of the transcript (*e.g.*, pre-mRNA) of the human dystrophin gene, exclusion of exon 50 occurs and, for example, the base sequence corresponding to the 5' end of exon 52 is connected to the base sequence corresponding to the 3' end of exon 49 in DMD patients with deletion of exon 51 when the transcript undergoes splicing, thus resulting in formation of mature mRNA which is free of codon frame shift.

[0029]

Thus, DMD patients having a mutation that is amenable to exon 50 skipping in the dystrophin gene can be treated by exon 50 skipping. Examples of such DMD patients include DMD patients who have the dystrophin gene that has at least a frameshift mutation caused by deletion of an exon in the vicinity of exon 50 and in which the amino acid reading frame is corrected by exon 50 skipping, and more specifically include DMD patients having a frameshift mutation caused by deletions of exons 51, 51-53, 51-55, 51-57, etc. in the dystrophin gene.

[0030]

Herein, the term "binding" described above is intended to mean that when the antisense oligomer of the present invention is mixed with the transcript of human dystrophin gene, both hybridize with each other under physiological conditions to form a double strand nucleic acid. The term "under physiological conditions" refers to conditions set to mimic the *in vivo* environment in terms of pH, salt composition and temperature. The conditions are, for example, 25 to 40°C, preferably 37°C, pH 5 to 8, preferably pH 7.4 and 150 mM of sodium chloride concentration.

[0031]

Whether the skipping of exon 50 in the human dystrophin gene is caused or not can be confirmed by introducing the antisense oligomer of the present invention into a dystrophin-expressing cell (*e.g.*, human rhabdomyosarcoma cells), amplifying the region surrounding exon 50 of mRNA of the human dystrophin gene from the total RNA of the dystrophin-expressing cell by RT-PCR and performing nested PCR or sequence analysis on the PCR amplified product. The skipping efficiency ES (%) can be determined as follows. The mRNA for the human dystrophin gene is collected from test cells; and in the mRNA, the polynucleotide level of the band showing that exon 50 is skipped (the polynucleotide level "A") and the polynucleotide level of the band showing that exon 50 is not skipped (the polynucleotide level "B") are measured. Using these measurement values of "A" and "B," the efficiency is calculated by the

following equation (1). For calculation of the skipping efficiency, International Publication WO2012/029986 may be referred.

[0032]

$$ES = 100 \times A / (A + B) \dots (1)$$

[0033]

Preferably, the antisense oligomer of the present invention cause skipping of exon 50 with the efficiency of 10% or higher, 20% or higher, 30% or higher, 40% or higher, 50% or higher, 60% or higher, 70% or higher, 80% or higher, and 90% or higher.

[0034]

The antisense oligomer of the present invention includes, for example, an oligonucleotide, morpholino oligomer or peptide nucleic acid (PNA) oligomer, having a length of 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34 or 35 bases. The length of the antisense oligomer is preferably from 16 to 25, from 16 to 23, 19 or 20 bases and morpholino oligomers are preferred.

[0035]

The oligonucleotide described above (hereinafter referred to as "the oligonucleotide of the present invention") is the antisense oligomer of the present invention composed of nucleotides as constituent units. Such nucleotides may be any of ribonucleotides, deoxyribonucleotides and modified nucleotides.

[0036]

The modified nucleotide refers to one having fully or partly modified nucleobases, sugar moieties and/or phosphate bond moieties, which constitute the ribonucleotide or deoxyribonucleotide.

[0037]

In the present invention, the nucleobase includes, for example, adenine, guanine, hypoxanthine, cytosine, thymine, uracil, and modified bases thereof. Examples of such modified bases include, but not limited to, pseudouracil, 3-

methyluracil, dihydrouracil, 5-alkylcytosines (*e.g.*, 5-methylcytosine), 5-alkyluracils (*e.g.*, 5-ethyluracil), 5-halouracils (5-bromouracil), 6-azapyrimidine, 6-alkylpyrimidines (6-methyluracil), 2-thiouracil, 4-thiouracil, 4-acetylcytosine, 5-(carboxyhydroxymethyl) uracil, 5'-carboxymethylaminomethyl-2-thiouracil, 5-carboxymethylaminomethyluracil, 1-methyladenine, 1-methylhypoxanthine, 2,2-dimethylguanine, 3-methylcytosine, 2-methyladenine, 2-methylguanine, N6-methyladenine, 7-methylguanine, 5-methoxyaminomethyl-2-thiouracil, 5-methylaminomethyluracil, 5-methylcarbonylmethyluracil, 5-methoxyuracil, 5-methyl-2-thiouracil, 2-methylthio-N6-isopentenyladenine, uracil-5-oxyacetic acid, 2-thiocytosine, purine, 2,6-diaminopurine, 2-aminopurine, isoguanine, indole, imidazole, xanthine, etc.

[0038]

Modification of the sugar moiety may include, for example, modifications at the 2'-position of ribose and modifications of the other positions of the sugar. The modification at the 2'-position of ribose includes a modification replacing the 2'-OH of ribose with OR, R, R'OR, SH, SR, NH₂, NHR, NR₂, N₃, CN, F, Cl, Br or I, wherein R represents an alkyl or an aryl and R' represents an alkylene.

The modification for the other positions of the sugar includes, for example, replacement of O at the 4' position of ribose or deoxyribose with S, bridging between 2' and 4' positions of the sugar, *e.g.*, LNA (locked nucleic acid) or ENA (2'-O,4'-C-ethylene-bridged nucleic acids), but is not limited thereto.

[0039]

A modification of the phosphate bond moiety includes, for example, a modification of replacing phosphodiester bond with phosphorothioate bond, phosphorodithioate bond, alkyl phosphonate bond, phosphoramidate bond or boranophosphate bond (Enya et al: Bioorganic & Medicinal Chemistry, 2008, 18, 9154-9160) (*cf.*, *e.g.*, Japan Domestic Re-Publications of PCT Application Nos. 2006/129594 and 2006/038608).

[0040]

In this invention, the alkyl includes preferably a straight or branched alkyl having 1 to 6 carbon atoms. Specific examples include methyl, ethyl, *n*-propyl, isopropyl, *n*-butyl, isobutyl, *sec*-butyl, *tert*-butyl, *n*-pentyl, isopentyl, neopentyl, *tert*-pentyl, *n*-hexyl and isohexyl. The alkyl may optionally be substituted. Examples of such substituents are a halogen, an alkoxy, cyano and nitro. The alkyl may be substituted with 1 to 3 substituents.

In this invention, the cycloalkyl includes preferably a cycloalkyl having 5 to 12 carbon atoms. Specific examples include cyclopentyl, cyclohexyl, cycloheptyl, cyclooctyl, cyclodecyl and cyclododecyl.

In this invention, the halogen includes fluorine, chlorine, bromine and iodine.

The alkoxy includes a straight or branched alkoxy having 1 to 6 carbon atoms such as methoxy, ethoxy, *n*-propoxy, isopropoxy, *n*-butoxy, isobutoxy, *sec*-butoxy, *tert*-butoxy, *n*-pentyloxy, isopentyloxy, *n*-hexyloxy, isohexyloxy, etc. Among others, an alkoxy having 1 to 3 carbon atoms is preferred.

[0041]

In this invention, the aryl includes preferably an aryl having 6 to 10 carbon atoms. Specific examples include phenyl, α -naphthyl and β -naphthyl. Among others, phenyl is preferred. The aryl may optionally be substituted. Examples of such substituents are an alkyl, a halogen, an alkoxy, cyano and nitro. The aryl may be substituted with one to three of such substituents.

In this invention, the alkylene includes preferably a straight or branched alkylene having 1 to 6 carbon atoms. Specific examples include methylene, ethylene, trimethylene, tetramethylene, pentamethylene, hexamethylene, 2-(ethyl) trimethylene and 1-(methyl) tetramethylene.

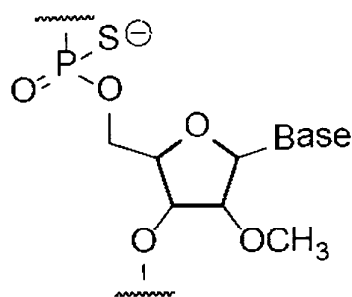
In this invention, the acyl includes a straight or branched alkanoyl or aroyl. Examples of the alkanoyl include formyl, acetyl, 2-methylacetyl, 2,2-dimethylacetyl, propionyl, butyryl, isobutyryl, pentanoyl, 2,2-dimethylpropionyl, hexanoyl, etc.

Examples of the aroyl include benzoyl, toluoyl and naphthoyl. The aroyl may optionally be substituted at substitutable positions and may be substituted with an alkyl(s).

[0042]

The oligonucleotide of the present invention is preferably the antisense oligomer of the present invention comprising a constituent unit represented by general formula below wherein the -OH group at position 2' of ribose is substituted with methoxy and the phosphate bond moiety is a phosphorothioate bond:

[Formula 2]



wherein Base represents a nucleobase.

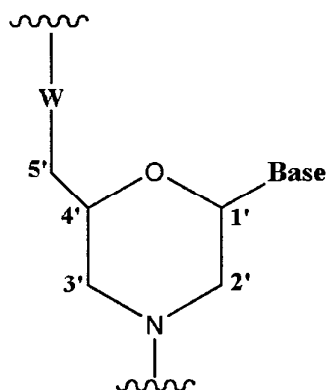
[0043]

The oligonucleotide of the present invention may be easily synthesized using various automated synthesizer (*e.g.*, AKTA oligopilot plus 10/100 (GE Healthcare)). Alternatively, the synthesis may also be entrusted to a third-party organization (*e.g.*, Promega Inc., Takara Co., or Japan Bio Service Co.), etc.

[0044]

The morpholino oligomer of the present invention is the antisense oligomer of the present invention comprising the constituent unit represented by general formula below:

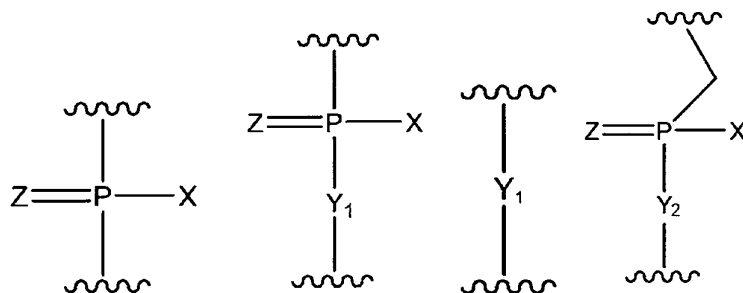
[Formula 3]



wherein Base has the same meaning as defined above, and W represents a group shown by any one of the following groups:

[0045]

[Formula 4]



wherein X represents $-\text{CH}_2\text{R}^1$, $-\text{O}-\text{CH}_2\text{R}^1$, $-\text{S}-\text{CH}_2\text{R}^1$, $-\text{NR}^2\text{R}^3$ or F;

R^1 represents H or an alkyl;

R^2 and R^3 , which may be the same or different, each represents H, an alkyl, a cycloalkyl or an aryl;

Y_1 represents O, S, CH_2 or NR^1 ;

Y_2 represents O, S or NR^1 ;

Z represents O or S.

[0046]

Examples of morpholino monomer compounds that are used in synthesis of the morpholino oligomer of the present invention include, but not limited to, the following morpholino monomer compound (A), morpholino monomer compound (C), morpholino monomer compound (T), and morpholino monomer compound (G).

[0047]

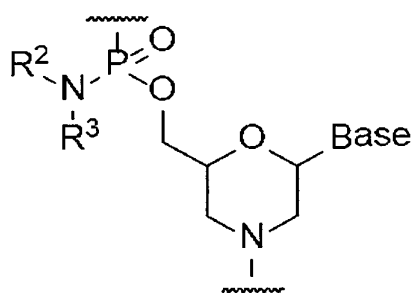
[Table 1]

Morpholino monomer compound (A)	Morpholino monomer compound (C)	Morpholino monomer compound (T)	Morpholino monomer compound (G)

[0048]

The morpholino oligomer is preferably an oligomer comprising a constituent unit represented by general formula below (phosphorodiamidate morpholino oligomer (hereinafter referred to as "PMO")).

[Formula 5]



wherein Base, R² and R³ have the same meaning as defined above.

The morpholino oligomer of the present invention comprises one where all or part of nucleobases, morpholine ring moieties, phosphate bond moieties, 3'-end and /or 5'-end which constitute the morpholino oligomer are modified.

[0049]

A modification of the phosphate bond moiety includes, for example, a modification of replacing with phosphorodiamidate bond, phosphorothioate bond, phosphorodithioate bond, alkylphosphonate bond, phosphoramidate bond and boranophosphate bond (Enya et al: Bioorganic & Medicinal Chemistry, 2008, 18, 9154-9160)(cf., *e.g.*, Japan Domestic Re-Publications of PCT Application Nos. 2006/129594 and 2006/038608).

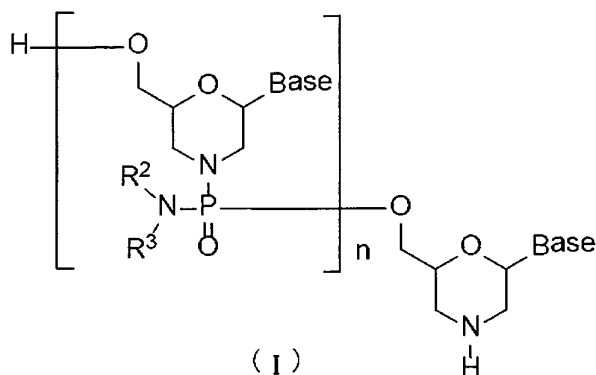
The morpholino oligomer may be produced in accordance with, *e.g.*, WO 1991/009033 or WO 2009/064471. In particular, PMO can be produced by the procedure described in WO 2009/064471 or produced by the process shown below.

[0050]

[Method for producing PMO]

An embodiment of PMO includes, for example, the compound represented by general formula (I) below (hereinafter PMO (I)).

[Formula 6]



wherein Base, R² and R³ have the same meaning as defined above; and,

n is a given integer of 1 to 99, preferably a given integer of 15 to 34, 15 to 24 or 15 to 22, more preferably 18 or 19.

[0051]

PMO (I) can be produced in accordance with a known method, for example, can be produced by performing the procedures in the following steps.

The compounds and reagents used in the steps below are not particularly limited so long as they are commonly used to prepare PMO.

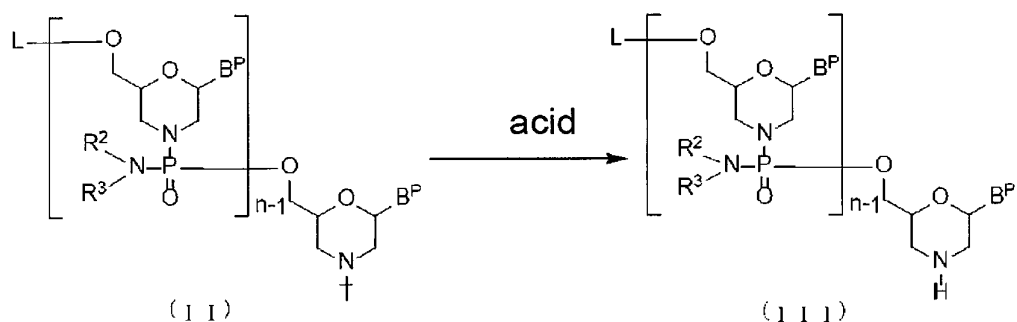
Also, the following steps can all be carried out by the liquid phase method or the solid phase method (by manually or using commercially available solid phase automated synthesizers). In producing PMO by the solid phase method, it is preferable to use automated synthesizers in view of simple operation procedures and accurate synthesis.

[0052]

(1) Step A:

The compound represented by general formula (II) below (hereinafter referred to as Compound (II)) is reacted with an acid to prepare the compound represented by general formula (III) below (hereinafter referred to as Compound (III)):

[Formula 7]



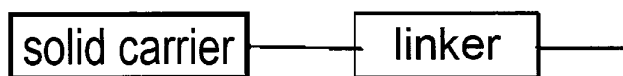
wherein n , R^2 and R^3 have the same meaning as defined above;

each B^{P} independently represents a nucleobase which may optionally be protected;

T represents trityl, monomethoxytrityl or dimethoxytrityl; and,

L represents hydrogen, an acyl or a group represented by general formula (IV) below (hereinafter referred to as group (IV)).

[Formula 8]



(I V)

[0053]

The "nucleobase" for B^P includes the same "nucleobase" as in Base, provided that the amino group or hydroxy group in the nucleobase shown by B^P may be protected.

Such protective group for amino group is not particularly limited so long as it is used as a protective group for nucleic acids. Specific examples include benzoyl, 4-methoxybenzoyl, acetyl, propionyl, butyryl, isobutyryl, phenylacetyl, phenoxyacetyl, 4-tert-butylphenoxyacetyl, 4-isopropylphenoxyacetyl and (dimethylamino)methylene. Specific examples of the protective group for the hydroxy group include 2-cyanoethyl, 4-nitrophenethyl, phenylsulfonylethyl, methylsulfonylethyl, trimethylsilylethyl, phenyl, which may be substituted by 1 to 5 electron-withdrawing group at optional substitutable positions, diphenylcarbamoyl, dimethylcarbamoyl, diethylcarbamoyl, methylphenylcarbamoyl, 1-pyrrolidinylcarbamoyl, morpholinocarbamoyl, 4-(tert-butylcarboxy) benzyl, 4-[(dimethylamino)carboxy]benzyl and 4-(phenylcarboxy)benzyl, (cf., *e.g.*, WO 2009/064471).

[0054]

The "solid carrier" is not particularly limited so long as it is a carrier usable for the solid phase reaction of nucleic acids. It is desired for the solid carrier to have the following properties: *e.g.*, (i) it is sparingly soluble in reagents that can be used for the synthesis of morpholino nucleic acid derivatives (*e.g.*, dichloromethane, acetonitrile, tetrazole, *N*-methylimidazole, pyridine, acetic anhydride, lutidine, trifluoroacetic

acid); (ii) it is chemically stable to the reagents that can be used for the synthesis of morpholino nucleic acid derivatives; (iii) it can be chemically modified; (iv) it can be charged with desired morpholino nucleic acid derivatives; (v) it has a strength sufficient to withstand high pressure through treatments; and (vi) it has a certain particle diameter range and distribution. Specifically, swellable polystyrene (*e.g.*, aminomethyl polystyrene resin 1% divinylbenzene crosslinked (200-400 mesh) (2.4-3.0 mmol/g) (Tokyo Chemical Industry), Aminomethylated Polystyrene Resin-HCl [divinylbenzene 1%, 100-200 mesh] (Peptide Institute, Inc.)), non-swellable polystyrene (*e.g.*, Primer Support (GE Healthcare)), PEG chain-attached polystyrene (*e.g.*, NH₂-PEG resin (Watanabe Chemical Co.), TentaGel resin), controlled pore glass (CPG) (manufactured by, *e.g.*, CPG), oxalyl-controlled pore glass (*cf.*, *e.g.*, Alul et al., Nucleic Acids Research, Vol. 19, 1527 (1991)), TentaGel support-aminopolyethylene glycol-derivatized support (*e.g.*, Wright et al., *cf.*, Tetrahedron Letters, Vol. 34, 3373 (1993)), and a copolymer of Poros-polystyrene/divinylbenzene.

A "linker" which can be used is a known linker generally used to connect nucleic acids or morpholino nucleic acid derivatives. Examples include 3-aminopropyl, succinyl, 2,2'-diethanolsulfonyl and a long chain alkyl amino (LCAA).

[0055]

This step can be performed by reacting Compound (II) with an acid.

[0056]

The "acid" which can be used in this step includes, for example, trifluoroacetic acid, dichloroacetic acid and trichloroacetic acid. The amount of acid used is appropriately in a range of, for example, 0.1 mol equivalent to 1000 mol equivalents for 1 mol of Compound (II), preferably in a range of 1 mol equivalent to 100 mol equivalents for 1 mol of Compound (II).

An organic amine can be used in combination with the acid described above. The organic amine is not particularly limited and includes, for example, triethylamine. The amount of the organic amine used is appropriately in a range of, *e.g.*, 0.01 mol

equivalent to 10 mol equivalents, and preferably in a range of 0.1 mol equivalent to 2 mol equivalents, for 1 mol of the acid.

When a salt or mixture of the acid and the organic amine is used in this step, the salt or mixture includes, for example, a salt or mixture of trifluoroacetic acid and triethylamine, and more specifically, a mixture of 1 equivalent of triethylamine and 2 equivalents of trifluoroacetic acid.

The acid which can be used in this step may also be used in the form of a dilution with an appropriate solvent in a concentration of 0.1% to 30%. The solvent is not particularly limited as far as it is inert to the reaction, and includes, for example, dichloromethane, acetonitrile, an alcohol(s) (ethanol, isopropanol, trifluoroethanol, etc.), water, or a mixture thereof.

[0057]

The reaction temperature in the reaction described above is preferably in a range of, *e.g.*, 10°C to 50°C, more preferably, in a range of 20°C to 40°C, and most preferably, in a range of 25°C to 35°C.

The reaction time may vary depending upon kind of the acid used and reaction temperature, and is appropriately in a range of 0.1 minute to 24 hours in general, and preferably in a range of 1 minute to 5 hours.

[0058]

After completion of this step, a base may be added, if necessary, to neutralize the acid remained in the system. The "base" is not particularly limited and includes, for example, diisopropylethylamine. The base may also be used in the form of a dilution with an appropriate solvent in a concentration of 0.1% (v/v) to 30% (v/v).

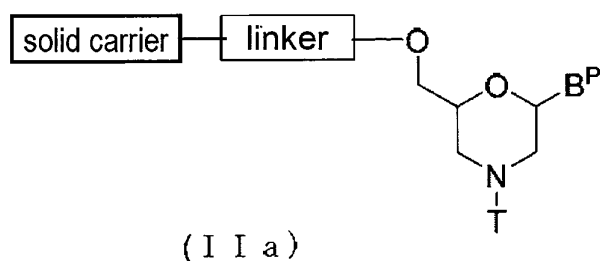
The solvent used in this step is not particularly limited so long as it is inert to the reaction, and includes dichloromethane, acetonitrile, an alcohol(s) (ethanol, isopropanol, trifluoroethanol, etc.), water, and a mixture thereof. The reaction temperature is preferably in a range of, *e.g.*, 10°C to 50°C, more preferably, in a range of 20°C to 40°C, and most preferably, in a range of 25°C to 35°C.

The reaction time may vary depending upon kind of the base used and reaction temperature, and is appropriately in a range of 0.1 minute to 24 hours in general, and preferably in a range of 1 minute to 5 hours.

[0059]

In Compound (II), the compound of general formula (IIa) below (hereinafter Compound (IIa)), wherein n is 1 and L is a group (IV), can be produced by the following procedure.

[Formula 9]



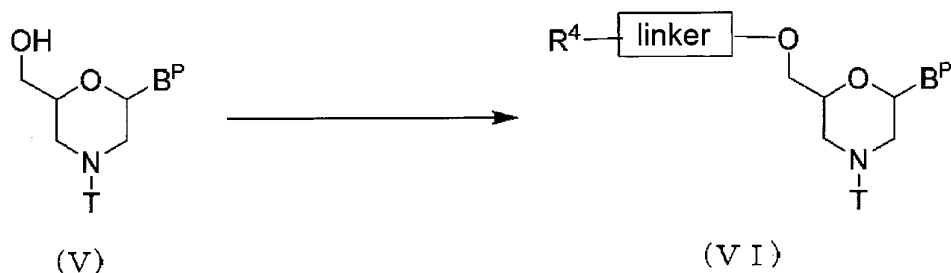
wherein B^P, T, linker and solid carrier have the same meaning as defined above.

[0060]

Step 1:

The compound represented by general formula (V) below is reacted with an acylating agent to prepare the compound represented by general formula (VI) below (hereinafter referred to as Compound (VI)).

[Formula 10]



wherein B^P, T and linker have the same meaning as defined above; and,

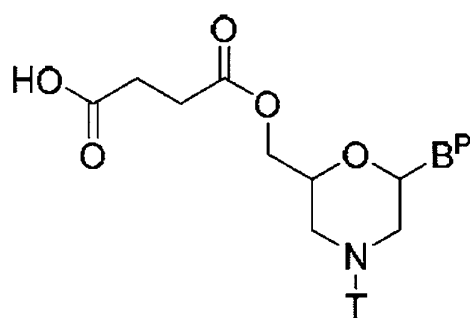
R⁴ represents hydroxy, a halogen, carboxyl group or amino.

[0061]

This step can be carried out by known procedures for introducing linkers, using Compound (V) as the starting material.

In particular, the compound represented by general formula (VIa) below can be produced by performing the method known as esterification, using Compound (V) and succinic anhydride.

[Formula 11]



(VI a)

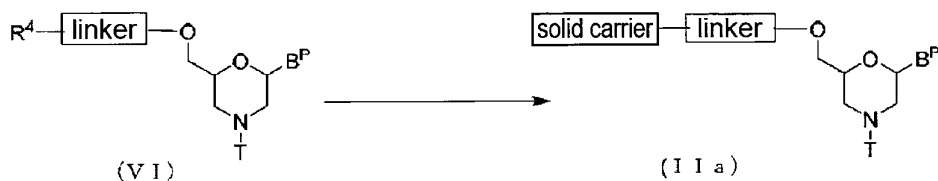
wherein B^P and T have the same meaning as defined above.

[0062]

Step 2:

Compound (VI) is reacted with a solid carrier by using a condensing agent or the like to prepare Compound (IIa).

[Formula 12]

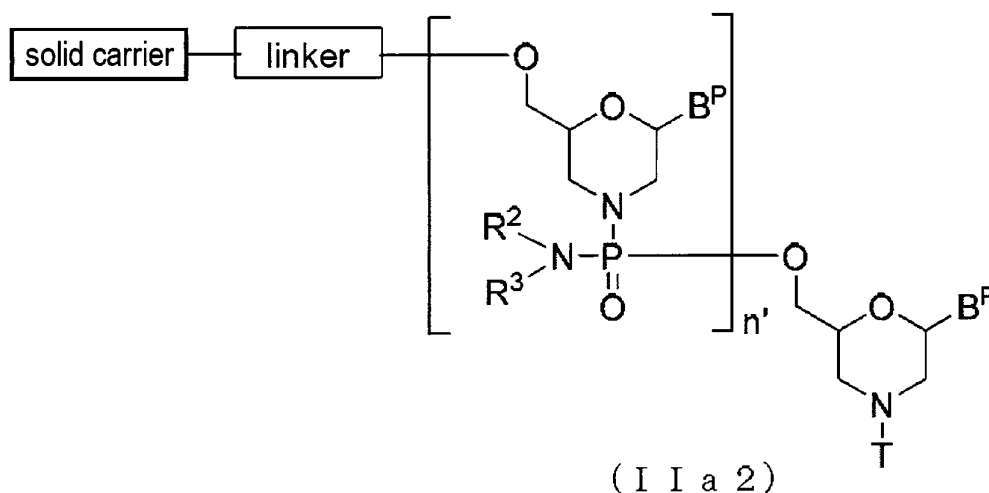


wherein B^P, R⁴, T, linker and solid carrier have the same meaning as defined above.

This step can be performed using Compound (VI) and a solid carrier in accordance with a process known as condensation reaction.

In Compound (II), the compound represented by general formula (IIa2) below wherein n is 2 to 99 (preferably a given integer of 16 to 35, 16 to 25 or 16 to 23, preferably 19 or 20) and L is a group represented by general formula (IV) can be produced by using Compound (IIa) as the starting material and repeating step A and step B of the PMO production method described in the specification for a desired number of times.

[Formula 13]



wherein B^P , R^2 , R^3 , T, linker and solid carrier have the same meaning as defined above;

and,

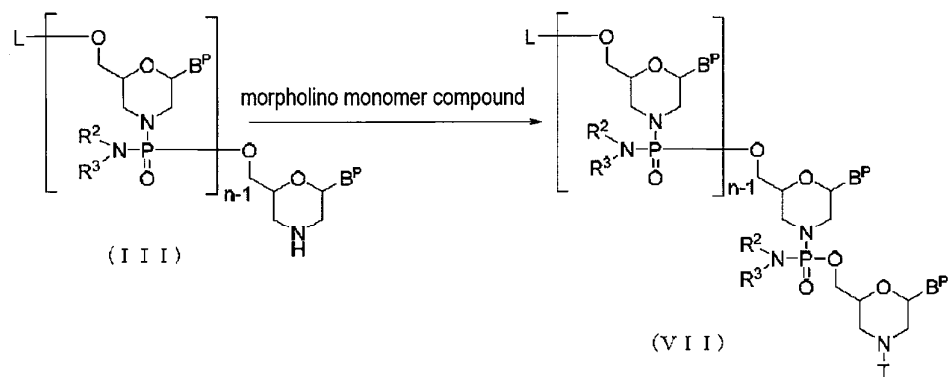
n' represents 1 to 98 (in a specific embodiment, n' is, for example, 1 to 34, 1 to 24, 1 to 23, 1 to 22, 1 to 21, 1 to 20, 1 to 19, 1 to 18, 1 to 17, 1 to 16, 1 to 15).

[0063]

(2) Step B

Compound (III) is reacted with a morpholino monomer compound in the presence of a base to prepare the compound represented by general formula (VII) below (hereinafter referred to as Compound (VII)):

[Formula 14]



wherein each B^P, L, n, R², R³ and T have the same meaning as defined above.

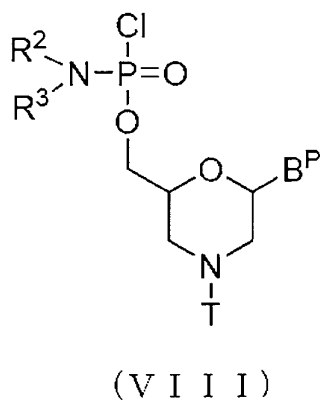
[0064]

This step can be performed by reacting Compound (III) with the morpholino monomer compound in the presence of a base.

[0065]

The morpholino monomer compound includes, for example, compounds represented by general formula (VIII) below:

[Formula 15]



wherein B^P, R², R³ and T have the same meaning as defined above.

The "base" which can be used in this step includes, for example, diisopropylethylamine, triethylamine and *N*-ethylmorpholine. The amount of the base used is appropriately, for example, in a range of 1 mol equivalent to 1000 mol

equivalents for 1 mol of Compound (III), preferably, 10 mol equivalents to 100 mol equivalents for 1 mol of Compound (III).

The morpholino monomer compound and base which can be used in this step may also be used as a dilution with an appropriate solvent in a concentration of 0.1% to 30%. The solvent is not particularly limited as far as it is inert to the reaction, and includes, for example, *N,N*-dimethylimidazolidone, *N*-methylpiperidone, DMF, dichloromethane, acetonitrile, tetrahydrofuran, or a mixture thereof.

[0066]

The reaction temperature is preferably in a range of, *e.g.*, 0°C to 100°C, and more preferably, in a range of 10°C to 50°C.

The reaction time may vary depending upon kind of the base used and reaction temperature, and is appropriately in a range of 1 minute to 48 hours in general, and preferably in a range of 30 minutes to 24 hours.

[0067]

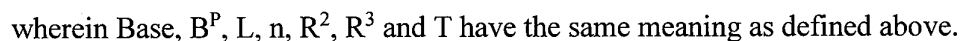
Furthermore, after completion of this step, an acylating agent can be added, if necessary. The "acylating agent" includes, for example, acetic anhydride, acetyl chloride and phenoxyacetic anhydride. The acylating agent may also be used as, for example, a dilution with an appropriate solvent in a concentration of 0.1% to 30%. The solvent is not particularly limited as far as it is inert to the reaction, and includes, for example, dichloromethane, acetonitrile, tetrahydrofuran, an alcohol(s) (ethanol, isopropanol, trifluoroethanol, etc.), water, or a mixture thereof.

If necessary, a base such as pyridine, lutidine, collidine, triethylamine, diisopropylethylamine, *N*-ethylmorpholine, etc. may also be used in combination with the acylating agent. The amount of the acylating agent used is preferably in a range of 0.1 mol equivalent to 10000 mol equivalents, and more preferably in a range of 1 mol equivalent to 1000 mol equivalents. The amount of the base used is appropriately in a range of, *e.g.*, 0.1 mol equivalent to 100 mol equivalents, and

The reaction temperature in this reaction is preferably in a range of 10°C to 50°C, more preferably, in a range of 10°C to 50°C, much more preferably, in a range of 20°C to 40°C, and most preferably, in a range of 25°C to 35°C. The reaction time may vary depending upon kind of the acylating agent used and reaction temperature, and is appropriately in a range of 0.1 minute to 24 hours in general, and preferably in a range of 1 minute to 5 hours.

(3) Step C:

[Formula 16]



This step can be performed by reacting Compound (VII) with a deprotecting agent.

The "deprotecting agent" includes, *e.g.*, conc. ammonia water and methylamine. The "deprotecting agent" used in this step may also be used as a dilution with, *e.g.*, water, methanol, ethanol, isopropyl alcohol, acetonitrile, tetrahydrofuran, DMF, *N,N*-dimethylimidazolidone, *N*-methylpiperidone, or a mixture of these solvents. Among

them, ethanol is preferred. The amount of the deprotecting agent used is appropriately, for example, in a range of 1 mol equivalent to 100000 mol equivalents, and preferably in a range of 10 mol equivalents to 1000 mol equivalents, for 1 mol of Compound (VII).

[0071]

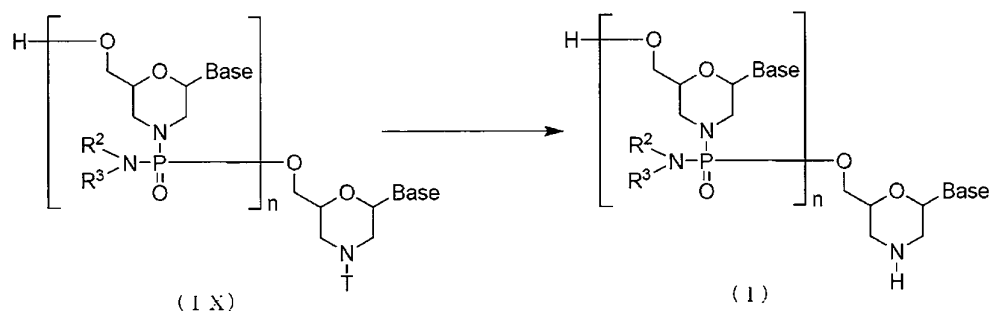
The reaction temperature is appropriately, for example, in a range of 15°C to 75°C, preferably, in a range of 40°C to 70°C, and more preferably, in a range of 50°C to 60°C. The reaction time for deprotection may vary depending upon kind of Compound (VII), reaction temperature, etc., and is appropriately in a range of 10 minutes to 30 hours, preferably 30 minutes to 24 hours, and more preferably in a range of 5 hours to 20 hours.

[0072]

(4) Step D:

PMO (I) is produced by reacting Compound (IX) produced in step C with an acid:

[Formula 17]



wherein Base, n, R², R³ and T have the same meaning as defined above.

[0073]

This step can be performed by adding an acid to Compound (IX).

[0074]

The "acid" which can be used in this step includes, for example, trichloroacetic acid, dichloroacetic acid, acetic acid, phosphoric acid, hydrochloric acid, etc. The

amount of acid used is appropriately used to allow the solution to have a pH range of 0.1 to 4.0, for example, and more preferably, in a range of pH 1.0 to 3.0. The solvent is not particularly limited so long as it is inert to the reaction, and includes, for example, acetonitrile, water, or a mixture of these solvents thereof.

[0075]

The reaction temperature is preferably in a range of 10°C to 50°C, more preferably, in a range of 20°C to 40°C, and more preferably, in a range of 25°C to 35°C. The reaction time for deprotection may vary depending upon kind of Compound (IX), reaction temperature, etc., and is appropriately in a range of 0.1 minute to 5 hours, preferably 1 minute to 1 hour, and more preferably in a range of 1 minute to 30 minutes.

[0076]

PMO (I) can be obtained by subjecting the reaction mixture obtained in this step to conventional means of separation and purification such as extraction, concentration, neutralization, filtration, centrifugal separation, recrystallization, reversed phase column chromatography using C₈ to C₁₈, cation exchange column chromatography, anion exchange column chromatography, gel filtration column chromatography, high performance liquid chromatography, dialysis, ultrafiltration, etc., alone or in combination thereof. Thus, the desired PMO (I) can be isolated and purified (cf., *e.g.*, WO 1991/09033).

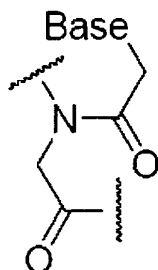
In purification of PMO (I) using reversed phase chromatography, as an elution solvent, *e.g.*, a solution mixture of 20 mM triethylamine/acetate buffer and acetonitrile can be used.

In purification of PMO (I) using ion exchange chromatography, as an elution solvent, *e.g.*, a solution mixture of 1 M saline solution and 10 mM sodium hydroxide aqueous solution can be used.

[0077]

A peptide nucleic acid is the antisense oligomer of the present invention having a group represented by the following general formula as the constituent unit:

[Formula 18]



wherein Base has the same meaning as defined above.

[0078]

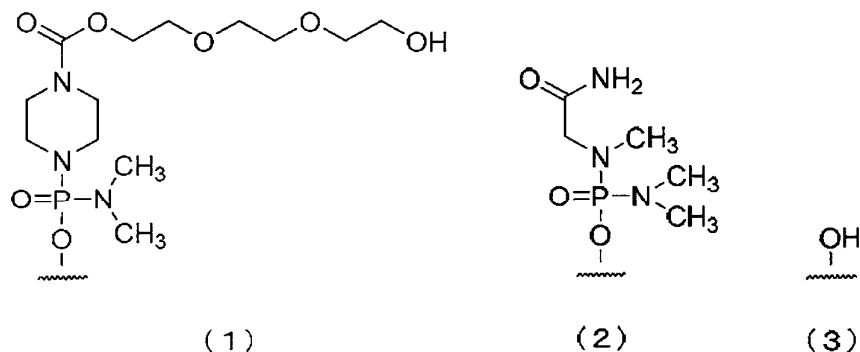
Peptide nucleic acids can be prepared by referring to, *e.g.*, the following literatures.

- 1) P. E. Nielsen, M. Egholm, R. H. Berg, O. Buchardt, *Science*, 254, 1497 (1991)
- 2) M. Egholm, O. Buchardt, P. E. Nielsen, R. H. Berg, *Jacs.*, 114, 1895 (1992)
- 3) K. L. Dueholm, M. Egholm, C. Behrens, L. Christensen, H. F. Hansen, T. Vulpus, K. H. Petersen, R. H. Berg, P. E. Nielsen, O. Buchardt, *J. Org. Chem.*, 59, 5767 (1994)
- 4) L. Christensen, R. Fitzpatrick, B. Gildea, K. H. Petersen, H. F. Hansen, T. Koch, M. Egholm, O. Buchardt, P. E. Nielsen, J. Coull, R. H. Berg, *J. Pept. Sci.*, 1, 175 (1995)
- 5) T. Koch, H. F. Hansen, P. Andersen, T. Larsen, H. G. Batz, K. Otteson, H. Orum, *J. Pept. Res.*, 49, 80 (1997)

[0079]

In the antisense oligomer of the present invention, the 5' end may be any one of the groups shown by the chemical formulae (1) to (3) below, and preferably is (3)-OH.

[Formula 19]



Hereinafter, the groups shown by (1), (2) and (3) above are referred to as "Group (1)," "Group (2)" and "Group (3)," respectively.

[0080]

The antisense oligomer of the present invention may comprise a compound with a stereochemically optically pure phosphorus atom because the phosphorus atom of the phosphate bond moiety serves as an asymmetric center. A person skilled in the art can obtain pure optically active forms from isomeric mixtures (WO2017/024264). The antisense oligomer of the present invention may be synthesized as a pure optically active form. A person skilled in the art can obtain pure optically active forms by controlling synthesis reactions (JP Laid-Open Publication No. 2018-537952).

[0081]

2. Peptide conjugated antisense oligomer

The antisense oligomer of the present invention may form a complex with a functional peptide aimed at improving effectiveness (*e.g.*, a membrane-permeable peptide aimed at improving efficacy of delivery to target cells) (WO2008/036127, WO2009/005793, WO2012/150960, WO2016/187425, WO2018/118662, WO2018/118599, WO2018/118627, J. D. Ramsey, N. H. Flynn, *Pharmacology & Therapeutics* 154, 78-86 (2015), M. K. Tsoumpira et al., *EBioMedicine*, <https://doi.org/10.1016/j.ebiom.2019.06.036>). The conjugation site is not

particularly limited. Preferably, the 5' end or 3' end of the antisense oligomer is connected (conjugated) to the amino terminal or carboxyl terminal of the functional peptide.

As another embodiment, the antisense oligomer of the present invention and the functional peptide may form a complex (conjugate) via a linker. The linker is not particularly limited. Preferably, the 5' end or 3' end of the antisense oligomer is connected to one end of the linker while the amino terminal or carboxyl terminal of the functional peptide is connected to the other end of the linker. An additional amino acid may exist between the functional peptide and the linker.

[0082]

3. Pharmaceutical composition

The antisense oligomer of the present invention, even if its length is short as compared to the prior art antisense oligomers, can induce exon 50 skipping with high efficiency. The antisense oligomer of the present invention has excellent solubility while maintaining an activity to induce exon 50 skipping with high efficiency. It is thus expected that conditions of muscular dystrophy can be ameliorated with high efficiency by administering the antisense oligomer of the present invention to DMD patients who have a mutation that is amenable to exon 50 skipping (*e.g.*, frameshift mutation and missense mutation/nonsense mutation in exon 50) in the dystrophin gene. It is thus expected that conditions of muscular dystrophy can be ameliorated with high efficiency by administering the antisense oligomer of the present invention, for example, at least to DMD patients who have predetermined mutant dystrophin gene having deletion of an exon in the vicinity of exon 50. The predetermined mutant dystrophin gene means the dystrophin gene which has at least a frameshift mutation caused by deletion of an exon in the vicinity of exon 50 and in which the amino acid reading frame is corrected by omission (skipping) of exon 50. Examples of the patients having such predetermined mutant dystrophin gene include DMD patients with a frameshift mutation caused by deletions of exons 51, 51-53, 51-55, 51-57, etc.

More specifically, it is expected that conditions of muscular dystrophy can be ameliorated with high efficiency by administering the pharmaceutical composition comprising the antisense oligomer of the present invention to DMD patients, who has mutation converting to in-frame by exon 50 skipping, for example, patients with deletion of exon 51, patients with deletion of exon 51-53, patients with deletion of exon 51-55, patients with deletion of exon 51-57, and so on). For example, when the pharmaceutical composition comprising the antisense oligomer of the present invention is used, the same therapeutic effects can be achieved even in a smaller dose than that of the oligomers of the prior art. Accordingly, side effects can be alleviated and such is economical.

The antisense oligomer of the present invention is also useful in preparation of pharmaceutical compositions because the antisense oligomer has excellent solubility while maintaining an activity to induce exon 50 skipping with high efficiency.

In another embodiment, the present invention provides the pharmaceutical composition for the treatment of muscular dystrophy, comprising as an active ingredient the antisense oligomer of the present invention, a pharmaceutically acceptable salt or hydrate thereof (hereinafter referred to as "the composition of the present invention").

Also, the present invention provides a method for treatment of muscular dystrophy, which comprises administering to a DMD patient the antisense oligomer of the present invention.

In the said method for treatment, the antisense oligomer of the present invention can be administered in the pharmaceutical composition for the treatment of muscular dystrophy.

Furthermore, the present invention provides the use of the antisense oligomer of the present invention in the manufacture of the pharmaceutical composition for treating muscular dystrophy and the antisense oligomer of the present invention for use in the treatment of muscular dystrophy.

[0083]

Examples of the pharmaceutically acceptable salt of the antisense oligomer of the present invention comprised in the composition of the present invention include alkali metal salts such as sodium salt, potassium salt and lithium salt; alkaline earth metal salts such as calcium salt and magnesium salt; metal salts such as aluminum salt, iron salt, zinc salt, copper salt, nickel salt, cobalt salt, etc.; ammonium salts; organic amine salts such as t-octylamine salt, dibenzylamine salt, morpholine salt, glucosamine salt, phenylglycine alkyl ester salt, ethylenediamine salt, *N*-methylglucamine salt, guanidine salt, diethylamine salt, triethylamine salt, dicyclohexylamine salt, *N,N'*-dibenzylethylenediamine salt, chlorprocaine salt, procaine salt, diethanolamine salt, *N*-benzylphenethylamine salt, piperazine salt, tetramethylammonium salt, tris(hydroxymethyl)aminomethane salt; hydrohalide salts such as hydrofluoric acid salt, hydrochloride salt, hydrobromide salt and hydroiodide salt; inorganic acid salts such as nitrate salt, perchlorate salt, sulfate salt, phosphate salt, etc.; lower alkane sulfonates such as methanesulfonate salt, trifluoromethanesulfonate salt and ethanesulfonate salt; arylsulfonate salt such as benzenesulfonate salt and p-toluenesulfonate salt; organic acid salts such as acetate salt, malate salt, fumarate salt, succinate salt, citrate salt, tartrate salt, oxalate salt, maleate salt, etc.; and, amino acid salts such as glycine salt, lysine salt, arginine salt, ornithine salt, glutamic acid salt and aspartic acid salt. These salts may be produced by known methods. Alternatively, the antisense oligomer of the present invention comprised in the composition of the present invention may be in the form of a hydrate thereof.

[0084]

Administration route for the composition of the present invention is not particularly limited so long as it is pharmaceutically acceptable route for administration, and can be chosen depending upon method of treatment. In view of easiness in delivery to muscle tissues, preferred are intravenous administration,

intraarterial administration, intramuscular administration, subcutaneous administration, oral administration, tissue administration, transdermal administration, etc. Also, dosage forms which are available for the composition of the present invention are not particularly limited, and include, for example, various injections, oral agents, drips, inhalations, ointments, lotions, etc.

[0085]

In administration of the antisense oligomer of the present invention to patients with muscular dystrophy, the composition of the present invention may comprise a carrier to promote delivery of the oligomer to muscle tissues. Such a carrier is not particularly limited as far as it is pharmaceutically acceptable, and examples include cationic carriers such as cationic liposomes, cationic polymers, etc., or carriers using viral envelope. Examples of the cationic liposomes include, for example, liposomes composed of 2-O-(2-diethylaminoethyl)carabamoyl-1,3-O-dioleoylglycerol and phospholipids as the essential constituents (hereinafter referred to as "liposome A"), Oligofectamine (registered trademark) (Invitrogen Corp.), Lipofectin (registered trademark) (Invitrogen Corp.), Lipofectamine (registered trademark) (Invitrogen Corp.), Lipofectamine 2000 (registered trademark) (Invitrogen Corp.), DMRIE-C (registered trademark) (Invitrogen Corp.), GeneSilencer (registered trademark) (Gene Therapy Systems), TransMessenger (registered trademark) (QIAGEN, Inc.), TransIT TKO (registered trademark) (Mirus) and Nucleofector II (Lonza). Among others, liposome A is preferred. Examples of cationic polymers include JetSI (registered trademark) (Qbiogene, Inc.) and Jet-PEI (registered trademark) (polyethylenimine, Qbiogene, Inc.). An example of carriers using viral envelop includes GenomeOne (registered trademark) (HVJ-E liposome, Ishihara Sangyo). Alternatively, the medical devices described in Japanese Patent No. 2924179 and the cationic carriers described in Japanese Domestic Re-Publication PCT Nos. 2006/129594 and 2008/096690 may be used as well.

For further details, U.S. Patent No. 4,235,871, U.S. Patent No. 4,737,323, WO96/14057, "New RRC, Liposomes: A practical approach, IRL Press, Oxford (1990) pages 33-104", etc. can be referred,

[0086]

A concentration of the antisense oligomer of the present invention comprised in the composition of the present invention may vary depending on kind of the carrier, etc., and in one embodiment, is appropriately in a range of 0.1 nM to 100 μ M, preferably in a range of 100 nM to 10 μ M. A weight ratio of the antisense oligomer of the present invention comprised in the composition of the present invention and the carrier (carrier/antisense oligomer of the present invention) may vary depending on property of the oligomer, type of the carrier, etc., and is appropriately in a range of 0.1 to 100, preferably in a range of 0.1 to 10.

[0087]

The composition of the present invention may be in the form of an aqueous solution. In this case, the composition of the present invention may comprise the antisense oligomer of the present invention in a concentration of 2.5 to 500 mg/mL, 5 to 450 mg/mL, 10 to 400 mg/mL, 15 to 350 mg/mL, 20 to 300 mg/mL, 20 to 250 mg/mL, 20 to 200 mg/mL, 20 to 150 mg/mL, 20 to 100 mg/mL, 20 to 50 mg/mL, 20 to 40 mg/mL, 20 to 30 mg/mL, 23 to 27 mg/mL, 24 to 26 mg/mL, or 25 mg/mL. Alternatively, the composition of the present invention may comprise the antisense oligomer of the present invention in a concentration of 10 to 100 mg/mL, 15 to 95 mg/mL, 20 to 80 mg/mL, 25 to 75 mg/mL, 30 to 70 mg/mL, 35 to 65 mg/mL, 40 to 60 mg/mL, 45 to 55 mg/mL, 47 to 53 mg/mL, 48 to 52 mg/mL, 49 to 51 mg/mL, or 50 mg/mL.

[0088]

The composition of the present invention may be in a dry form. In this case, in order to prepare the composition of the present invention in an aqueous solution form, the composition of the present invention in a dry form comprising, for example,

125 mg or 250 mg of the antisense oligomer of the present invention in a dry form may be mixed with 0.5 mL to 100 mL of water (which corresponds to the antisense oligomer of the present invention in a concentration of 1.25 mg/mL to 250 mg/mL or 2.5 mg/mL to 500 mg/mL), preferably with 1 mL to 50 mL of water (which corresponds to the antisense oligomer of the present invention in a concentration of 2.5 mg/mL to 125 mg/mL or 5 mg/mL to 250 mg/mL), more preferably with 5 mL to 10 mL of water (which correspond to the antisense oligomer of the present invention in a concentration of 12.5 mg/mL to 25 mg/mL or 25 mg/mL to 50 mg/mL) and used.

[0089]

In addition to the antisense oligomer of the present invention and the carrier described above, pharmaceutically acceptable additives may also be optionally formulated in the composition of the present invention. Examples of such additives are emulsification aids (*e.g.*, fatty acids having 6 to 22 carbon atoms and their pharmaceutically acceptable salts, albumin and dextran), stabilizers (*e.g.*, cholesterol, phosphatidic acid, sucrose, mannitol, sorbitol and xylitol), isotonicizing agents (*e.g.*, sodium chloride, glucose, maltose, lactose, sucrose, trehalose, mannitol, sorbitol and xylitol), and pH controlling agents (*e.g.*, hydrochloric acid, sulfuric acid, phosphoric acid, acetic acid, sodium hydroxide, potassium hydroxide and triethanolamine). One or more of these additives can be used. The content of the additive in the composition of the present invention is appropriately 90 wt% or less, preferably 70 wt% or less and more preferably, 50 wt% or less.

[0090]

The composition of the present invention can be prepared by adding the antisense oligomer of the present invention to a carrier dispersion and adequately stirring the mixture. Additives may be added at an appropriate step either before or after addition of the antisense oligomer of the present invention. When the composition of the present invention is in the form of an aqueous solution, an aqueous solvent that can be used in adding the antisense oligomer of the present invention is

not particularly limited as far as it is pharmaceutically acceptable, and examples of the aqueous solvent include injectable water or injectable distilled water, electrolyte fluid such as physiological saline, etc., and sugar fluid such as glucose fluid, maltose fluid, etc. A person skilled in the art can appropriately choose conditions for pH and temperature for such case.

[0091]

The composition of the present invention may be prepared into, *e.g.*, a liquid form and its lyophilized preparation. In one embodiment of the composition of the present invention in a dry form, the lyophilized preparation can be prepared by lyophilizing the composition of the present invention in a liquid form in a conventional manner. The lyophilization can be performed, for example, by appropriately sterilizing the composition of the present invention in a liquid form, dispensing an aliquot into a vial container, performing preliminary freezing for 2 hours at conditions of about -40 to -20°C, performing a primary drying at about 0 to 10°C under reduced pressure, and then performing a secondary drying at about 15 to 25°C under reduced pressure. In general, the lyophilized preparation of the composition of the present invention can be then obtained by replacing the gas of the vial with nitrogen gas and capping.

[0092]

The lyophilized preparation of the composition of the present invention can be used in general upon reconstitution by adding an optional suitable solution (reconstitution liquid) and redissolving the preparation. Such a reconstitution liquid includes injectable water, physiological saline and other infusion fluids. A volume of the reconstitution liquid may vary depending on the intended use, etc., is not particularly limited, and is suitably 0.5 to 2-fold greater than the volume prior to lyophilization or no more than 500 mL.

[0093]

It is desired to control a dose of the composition of the present invention to be administered, by taking the following factors into account: the type and dosage form of the antisense oligomer of the present invention comprised in the composition; patients' conditions including age, body weight, etc.; administration route; and the characteristics and extent of the disease. A daily dose calculated as the amount of the antisense oligomer of the present invention is generally in a range of 0.1 mg to 10 g/human, and preferably 1 mg to 1 g/human. This numerical range may vary occasionally depending on type of the target disease, administration route and target molecule. Therefore, a dose lower than the range may be sufficient in some occasion and conversely, a dose higher than the range may be required occasionally. The composition can be administered from once to several times daily or at intervals from one day to several days.

[0094]

In another embodiment of the composition of the present invention, there is provided a pharmaceutical composition comprising a vector capable of expressing the oligonucleotide of the present invention and the carrier described above. Such an expression vector may be a vector capable of expressing a plurality of the oligonucleotides of the present invention. The composition may be formulated with pharmaceutically acceptable additives as in the case with the composition of the present invention comprising the antisense oligomer of the present invention. A concentration of the expression vector comprised in the composition may vary depending upon type of the carrier, etc., and in one embodiment, is appropriately in a range of 0.1 nM to 100 μ M, preferably in a range of 100 nM to 10 μ M. A weight ratio of the expression vector and the carrier comprised in the composition (carrier/expression vector) may vary depending on property of the expression vector, type of the carrier, etc., and is appropriately in a range of 0.1 to 100, preferably in a range of 0.1 to 10. The content of the carrier comprised in the composition is the same as in the case with the composition of the present invention comprising the

antisense oligomer of the present invention, and a method for producing the same is also the same as in the case with the composition of the present invention.

[0095]

Hereinafter, the present invention will be described in more detail with reference to Examples and Test Examples below, but is not deemed to be limited thereto.

[Examples]

[0096]

[Example 1: Production of antisense oligomer]

According to the method described in WO2013/100190, the antisense oligomers shown in Table 1 (PMO Nos. 1 to 7 (SEQ ID NOs: 2 to 8)) which targeted a partial base sequence of exon 50 and/or its 3' adjacent intron (intron 50) in the human dystrophin gene were synthesized. The full length of each antisense oligomer was from 19 to 21 mer. The theoretical value of the molecular weight of each antisense oligomer and the found value thereof by ESI-TOF-MS are also shown.

In Table 1, for example, "H50_109-129" represents that when the 5'-terminal base of exon 50 in the human dystrophin gene is counted as the 1st base and its downstream bases to the 3' direction are numbered in order, the antisense oligomer targets the sequence of the 109th to 129th bases. Since the full length of exon 50 is 109 bases, the sequence of the 110th to 130th bases in the target base sequence is a base sequence in intron 50 in this example.

[Table 2]

Table 1 Synthesized antisense oligomers (PMO Nos. 1 to 7)

PMO No.	Target base sequence	Full length	Base sequence of PMO	Molecular weight		SEQ ID NO
				Theoretical value	Found value	
1	H50_109-129	21	ATGGGATCCAGTATACTTACA	6946. 42	6946. 25	2
2	H50_110-129	20	ATGGGATCCAGTATACTTAC	6607. 30	6607. 72	3
3	H50_110-128	19	TGGGATCCAGTATACTTAC	6268. 18	6268. 26	4
4	H50_111-129	19	ATGGGATCCAGTATACTTA	6292. 19	6291. 8	5
5	H50_107-125	19	GATCCAGTATACTTACAGG	6277. 19	6276. 75	6
6	H50_108-126	19	GGATCCAGTATACTTACAG	6277. 19	6277. 13	7
7	H50_112-130	19	AATGGGATCCAGTATACTT	6292. 19	6292. 97	8

[0097]

[Example 2: Exon skipping activity test of antisense oligomer]

In vitro test of exon 50 skipping in human dystrophin gene

(1) Testing method

Using an Amaxa Cell Line Nucleofector Kit L and Nucleofector II (Lonza), 0.1 to 1 μ M of each antisense oligomer of Table 1 was transfected to 3.5×10^5 of RD cells (human rhabdomyosarcoma cell line, CCL-136, purchased from ATCC)). The pulse program used for the transfection was T-030.

After transfection, the RD cells were cultured for three nights in 2 mL of Eagle's minimal essential medium (EMEM) (Sigma, hereinafter the same) containing 10% fetal bovine serum (FBS) (Invitrogen) under conditions of 37°C and 5% CO₂.

The transfected RD cells were washed once with PBS (Nissui, hereinafter the same) and 350 μ L of Buffer RA1 (Takara Bio Inc.) containing 1% 2-mercaptoethanol (Nacalai Tesque, Inc.) was added to the cells. After the cells were allowed to stand at room temperature for a few minutes to lyse the cells, the lysate was collected onto NucleoSpin (registered trademark) Filter (Takara Bio Inc.). A homogenate was produced by centrifugation at $11,000 \times g$ for 1 minute. The total RNA was extracted from the cells according to the protocol attached to NucleoSpin (registered trademark) RNA (Takara Bio Inc.). The concentration of the total RNA extracted was determined using a NanoDrop ONE (Thermo Fisher Scientific Inc.).

[0098]

One-Step RT-PCR was performed with 400 ng of the extracted total RNA using a QIAGEN One Step RT-PCR Kit (Qiagen) and a thermal cycler. A reaction solution was prepared in accordance with the protocol attached to the kit. The thermal cycler used was TaKaRa PCR Thermal Cycler Dice Touch (Takara Bio Inc.). The RT-PCR program used was as follows.

50°C, 30 minutes: reverse transcription reaction

95°C, 15 minutes: polymerase activation, reverse transcriptase inactivation, cDNA thermal denaturation

[94°C, 30 seconds; 60°C, 30 seconds; 72°C, 1 minute] × 35 cycles: PCR amplification

72°C, 10 minutes: final extension

[0099]

The base sequences of the forward primer and reverse primer used for RT-PCR are given below.

Forward primer: 5'- AACAAACCGGATGTGGAAGAG -3' (SEQ ID NO: 9)

Reverse primer: 5'- TTGGAGATGGCAGTTTCCTT -3' (SEQ ID NO: 10)

[0100]

The reaction product, 1 µL of the PCR above was analyzed using a Bioanalyzer (Agilent Technologies, Inc.) and MultiNA (Shimadzu Corp.).

The polynucleotide level of the band showing that exon 50 was skipped (the polynucleotide level "A") and the polynucleotide level of the band showing that exon 50 was not skipped (the polynucleotide level "B") were measured as signal intensities of the bands. Based on these measurement values of "A" and "B", the skipping efficiency was determined by the equation (1) mentioned above.

[0101]

(2) Test results

Figures 1 to 3 show the results about the exon 50 skipping efficiency obtained as to each antisense oligomer. Tables 2 to 4 below show the value of an effective concentration (EC_{50}) in which each antisense oligomer exhibits 50% skipping efficiency ES, which was calculated from these results. This test revealed that PMO Nos. 1 to 4 among the antisense oligomers had high skipping efficiency ES and a low EC_{50} value and therefore, effectively caused exon 50 skipping.

Among the antisense oligomers with a full length as short as 19 mer, as in PMO Nos. 3 and 4, PMO Nos. 5 to 7 had low skipping efficiency and a high EC_{50} value. The degree of overlap is also large between the base sequences targeted by PMO Nos. 3 and 4 and PMO Nos. 5 to 7. Therefore, the effectiveness of PMO Nos. 3 and 4 for exon 50 skipping is notable.

These results demonstrated that the antisense oligomer of the present invention, even if its length is short as compared to the prior art, can induce exon 50 skipping with high efficiency.

[Table 3]

Table 2 EC_{50} of antisense oligomers (PMO Nos. 1 and 2)

PMO No.	EC_{50} (μ M)	EC_{50} (μ g/mL)
1	0.45	3.12
2	0.49	3.22

[Table 4]

Table 3 EC_{50} of antisense oligomers (PMO Nos. 1, 3, and 4)

PMO No.	EC_{50} (μ M)	EC_{50} (μ g/mL)
1	0.31	2.16
3	0.45	2.82
4	0.52	3.28

[Table 5]

Table 4 EC₅₀ of antisense oligomers (PMO Nos. 1, 5, 6, and 7)

PMO No.	EC ₅₀ (μ M)	EC ₅₀ (μ g/mL)
1	0. 41	2. 87
5	16. 08	100. 99
6	3. 13	9. 78
7	1. 23	7. 75

[0102]

[Example 3: Solubility test of antisense oligomer]

Solubility test of antisense oligomer in physiological saline

Among the antisense oligomers with high skipping efficiency ES in Example 2, each antisense oligomer of PMO Nos. 2, 3, and 4 which had a full length as short as 19 to 20 mer and were conveniently synthesized was tested for its solubility in physiological saline in order to further verify usefulness for medical application.

[0103]

(1) Testing method

45 μL of physiological saline was added to a sample bottle containing 4.5 mg of each antisense oligomer above and stirred using ultrasonic waves and vortex to prepare a 100 mg/mL physiological saline solution. A sequence that caused no precipitation when allowed to stand at room temperature for 24 hours was evaluated as having high solubility.

[0104]

(2) Test Results

All the antisense oligomers tested exhibited solubility equal to or higher than 100 mg/mL in physiological saline. These antisense oligomers are antisense oligomers highly useful as medicaments because of their high efficiency of exon 50 skipping as well as high solubility in physiological saline.

These results demonstrated that the antisense oligomer of the present invention has excellent physical properties as medicaments while maintaining an activity to induce exon 50 skipping in the dystrophin gene with high efficiency.

[Industrial Applicability]

[0105]

Experimental results in Test Examples demonstrated that the antisense oligomers of the present invention induced exon 50 skipping with markedly high efficiency in RD cells. Therefore, the antisense oligomers of the present invention are extremely useful for the treatment of DMD.

[Free Text of Sequence Listing]

[0106]

SEQ ID NOs: 1 to 10: synthetic nucleic acids

[Document Name] Claims

[Claim 1]

An antisense oligomer which is selected from the group consisting of (a) to (d) below:

- (a) an antisense oligomer comprising a base sequence of any of SEQ ID NOs: 3 to 5;
 - (b) an antisense oligomer which comprises a base sequence having deletion, substitution, insertion and/or addition of 1 to 5 base(s) in the base sequence of any of SEQ ID NOs: 3 to 5, and has an activity to induce skipping of exon 50 in the human dystrophin gene;
 - (c) an antisense oligomer which comprises a base sequence having at least 80% sequence identity to a base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene; and
 - (d) an antisense oligomer that hybridizes under stringent conditions to an oligonucleotide consisting of a base sequence complementary to the base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene,
- or a pharmaceutically acceptable salt or hydrate thereof.

[Claim 2]

An antisense oligomer which is selected from the group consisting of (e) to (h) below:

- (e) an antisense oligomer which consists of a base sequence of any of SEQ ID NOs: 3 to 5;
- (f) an antisense oligomer which consists of a base sequence having deletion and/or substitution of 1 to 5 base(s) in the base sequence of any of SEQ ID NOs: 3 to 5, and has an activity to induce skipping of exon 50 in the human dystrophin gene;

(g) an antisense oligomer which consists of a base sequence having at least 80% sequence identity to a base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene; and

(h) an antisense oligomer that hybridizes under high stringent conditions to an oligonucleotide consisting of a base sequence complementary to the base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene,

or a pharmaceutically acceptable salt or hydrate thereof.

[Claim 3]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to claim 1 or 2, wherein

the antisense oligomer is

an antisense oligomer which has a nucleotide sequence having at least 90% sequence identity to a base sequence of any of SEQ ID NOs: 3 to 5 and has an activity to induce skipping of exon 50 in the human dystrophin gene.

[Claim 4]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any one of claims 1 to 3, wherein the antisense oligomer is an oligonucleotide.

[Claim 5]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to claim 4, wherein the sugar moiety and/or the phosphate bond moiety of at least one nucleotide constituting the oligonucleotide are/is modified.

[Claim 6]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to claim 4 or 5, wherein the sugar moiety of at least one nucleotide constituting the oligonucleotide is a ribose in which the 2'-OH group is replaced by

any one selected from the group consisting of OR, R, R'OR, SH, SR, NH₂, NHR, NR₂, N₃, CN, F, Cl, Br and I (wherein R is an alkyl or an aryl and R' is an alkylene).

[Claim 7]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any one of claims 4 to 6, wherein the phosphate bond moiety of at least one nucleotide constituting the oligonucleotide is any one selected from the group consisting of a phosphorothioate bond, a phosphorodithioate bond, an alkylphosphonate bond, a phosphoramidate bond and a boranophosphate bond.

[Claim 8]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any one of claims 1 to 3, wherein the antisense oligomer is a morpholino oligomer.

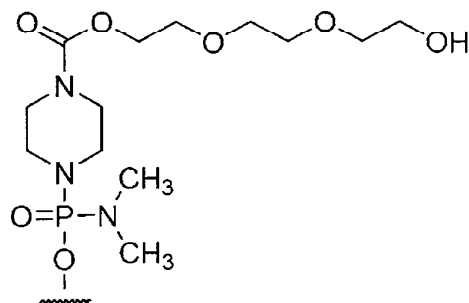
[Claim 9]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to claim 8, wherein the antisense oligomer is a phosphorodiamidate morpholino oligomer.

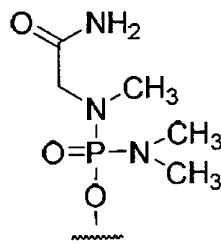
[Claim 10]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to claim 8 or 9, wherein the 5' end is any one of chemical formulae (1) to (3) below:

[Formula 1]



(1)



(2)



(3)

[Claim 11]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any one of claims 1 to 10, wherein the length of the antisense oligomer is 19 or 20 bases.

[Claim 12]

A pharmaceutical composition for the treatment of muscular dystrophy, comprising the antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any one of claims 1 to 11.

[Claim 13]

The pharmaceutical composition according to claim 12, further comprising a pharmaceutically acceptable carrier.

[Claim 14]

The pharmaceutical composition according to claim 12 or 13 for being administered to a patient with muscular dystrophy, wherein the patient is a patient having a mutation that is amenable to exon 50 skipping in the dystrophin gene.

[Claim 15]

The pharmaceutical composition according to claim 14, wherein the patient has the dystrophin gene that has at least a frameshift mutation caused by deletion of an exon in the vicinity of exon 50 and in which the amino acid reading frame is corrected by exon 50 skipping.

[Claim 16]

The pharmaceutical composition according to claim 14 or 15, wherein the patient has a frameshift mutation caused by deletions of exons 51, 51-53, 51-55, or 51-57 in the dystrophin gene.

[Claim 17]

The pharmaceutical composition according to any one of claims 14 to 16, wherein the patient is a human.

[Claim 18]

Use of the antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any one of claims 1 to 11 in the manufacture of a medicament for the treatment of muscular dystrophy.

[Claim 19]

A method for treatment of muscular dystrophy, which comprises administering to a patient with muscular dystrophy an effective amount of the antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any one of claims 1 to 11, or the pharmaceutical composition according to any one of claims 12 to 16.

[Claim 20]

The method for treatment according to claim 19, wherein the patient is a human.

[Claim 21]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof according to any one of claims 1 to 11, or the pharmaceutical composition according to any one of claims 12 to 16 for use in the treatment of muscular dystrophy.

[Claim 22]

The antisense oligomer or the pharmaceutically acceptable salt or hydrate thereof, or the pharmaceutical composition according to claim 21, wherein in the treatment, a patient with muscular dystrophy is a human.