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(54) Titre : PROCEDE DE TRAITEMENT ET DE PRONOSTIC DE SOUS-GROUPES DE PATIENTS SCOLIOTIQUES
(54) Title: METHOD OF TREATING AND PROGNOSING SCOLIOTIC PATIENT SUBGROUPS

FIGURE 1

Functional group	Effect of OPN	Initial Circulating [OPN]	Brace treatment	Other treatment options (See also Figure 1B)
FG1	Protective	high	No	Increase OPN level or activity (e.g., OPN, OPN agonist. Treatment and preventive measures which increase OPN levels)
		low	Generally, no	Increase OPN level or activity (e.g., OPN, OPN agonist. Treatment and preventive measures which increase OPN levels)
FG2	Risk factor	high	Yes	Decrease OPN level or activity (e.g., OPN antagonist. Treatment and preventive measures which decrease OPN levels)
		low	Yes,	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels)
FG3	Risk factor	high	Yes	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels)
		low	Yes	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels)

(57) **Abrégé/Abstract:**

The present invention provides a method of predicting brace treatment outcome in a subject in need thereof comprising i) classifying the subject into functional group FG1, FG2 or FG3, wherein the classification enables the prediction of brace treatment outcome. Also provided are methods of determining risk of developing scoliosis, methods of treating Idiopathic scoliosis and kits for applying the methods.



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(54) Title: METHOD OF TREATING AND PROGNOSING SCOLIOTIC PATIENT SUBGROUPS

FIGURE 1

Functional group	Effect of OPN	Initial Circulating [OPN]	Brace treatment	Other treatment options (See also Figure 1B)
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FG2	Risk factor	high	Yes	Decrease OPN level or activity (e.g., OPN antagonist. Treatment and preventive measures which decrease OPN levels.)
		low	Yes,	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels.)
FG3	Risk factor	high	Yes	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels.)
		low	Yes	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels.)

(57) Abstract: The present invention provides a method of predicting brace treatment outcome in a subject in need thereof comprising i) classifying the subject into functional group FG1, FG2 or FG3, wherein the classification enables the prediction of brace treatment outcome. Also provided are methods of determining risk of developing scoliosis, methods of treating Idiopathic scoliosis and kits for applying the methods.

TITLE OF THE INVENTION

METHOD OF TREATING AND PROGNOSING SCOLIOTIC PATIENT SUBGROUPS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application is a PCT application Serial No PCT/CA2014/* filed on September 9, 2014 and published in English under PCT Article 21(2), which itself claims benefit of U.S. provisional application Serial No. 61/875,162, filed on September 9, 2013 and of U.S. provisional application Serial No. 61/879,314, filed on September 18, 2013. All documents above are incorporated herein in their entirety by reference.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] N.A.

FIELD OF THE INVENTION

[0003] The present invention relates to Idiopathic Scoliosis (IS). More specifically, the present invention is concerned with endogenous osteopontin (OPN) levels, biological endophenotypes and IS treatment and prognostic.

REFERENCE TO SEQUENCE LISTING

[0004] N.A.

BACKGROUND OF THE INVENTION

[0005] IS (*e.g.*, Infantile Idiopathic scoliosis, Juvenile Idiopathic scoliosis or Adolescent Idiopathic scoliosis (AIS)) is a spine deformity of unknown cause generally defined as a lateral curvature greater than 10 degrees accompanied by a vertebral rotation ⁷. The condition affects 4 % of the paediatric population and is most commonly diagnosed between the ages of 9 to 13 years ^{8, 9, 10}.

[0006] Today in the United States there are approximately one million children between ages 10 and 16 with some degree of IS and about 100 000 children in Canada are diagnosed with IS. The total cost of diagnosis and monitoring of the scoliotic children by X-ray exposure is over \$2.5 billion dollars annually in North America. Approximately, 10 % of children diagnosed with idiopathic scoliosis have curve progression requiring corrective surgery ¹¹. About 29,000 scoliosis surgeries are done every year in North America, resulting in significant psychological and physical morbidity.

[0007] At the clinical level, the heterogeneity of IS is clearly illustrated by the variability of curve patterns, localisations and curve magnitude even in families with multiple affected members. In this regard, Applicants have previously discovered that scoliotic patients and subjects at risk of developing scoliosis are less responsive to G_i protein (inhibitory guanine nucleotide binding protein in G protein coupled receptors (GPCRs) also known as G_i alpha subunit) stimulation when compared with healthy control subjects. The presence of a general differential G_i -signaling dysfunction allowed to stratify patients into three functional groups (FG1, FG2 and FG3) representing distinct biological endophenotypes. This impairment was measured in all cell types tested including bone-forming cells; muscle-forming cells and blood cells. Furthermore, because the G_i cellular response impairment is generalized and not specific to a particular receptor, any G_i -PCR ligand (e.g., agonist) can be used to classify subjects.

[0008] A first classification method is based on the percentage of degree of reduction (inhibitory response) relative to control group. The classification ranges were fixed between about 10 and 40 % (or below 40%) of reduction of response relative to control group for FG3, about 40 and 60 % for FG2 and above about 60% (e.g., between about 60% and 90 %) for FG1. The same the classification ranges can be expressed as the percentage of maximal response relative to the control (as opposed to the % of reduction of response relative to the control). In such a case, the ranges are fixed between about 10-40% for FG1, about 40 and 60% for FG2 and about 60-90% for FG3. Both classification ranges can be used interchangeably (see, Moreau et al., 2004; Akoume et al., 2010; Akoume et al., 2013, Azeddine et al., 2007; Letellier et al., 2008; WO2003/073102, WO2010/040234 to Moreau, which are incorporated herein by reference in their entirety).

[0009] More recently, Applicants have modified this approach by demonstrating that the three functional groups can clearly be distinguished according to the profile of imbalance between response to G_i and G_s stimulation (i.e. G_i response minus G_s response or ratio between G_i/G_s stimulation or G_i/G_s -see PCT/CA2014/050562, which is incorporated herein by reference). It was found that the response to G_i stimulation predominated in FG3, while no apparent (i.e., no substantial or a very small) imbalance was observed in FG2. In contrast, FG1 subjects exhibited predominance for response to G_s stimulation. In addition, evidence was provided to the effect that patients belonging to the FG2 endophenotype are more at risk of progressing to the point of needing surgery (Julien et al., (2013)).

[0010] The differences in G_i -mediated cellular response observed among the three

endophenotypes is a consequence of differences observed at the level of Gi protein phosphorylation. When Gi α proteins are phosphorylated they become inactive. The inventors have shown that the degree of serine phosphorylation of Gi α proteins can alternatively be used to classify subjects into a specific functional groups. In FG1 subjects, all Gi α proteins (Gi α 1-3) are phosphorylated and their level of serine phosphorylation is substantially higher than in control subjects. In FG2 subjects, Gi α 1 and Gi α 2 are phosphorylated, the level of Gi α 1 and Gi α 2 phosphorylation is higher than in control subjects and most Gi α 3 proteins are not phosphorylated and thus, remain functional. Finally, in FG3 subjects Gi α 2 and Gi α 3 are phosphorylated, their level of phosphorylation is higher than in control subjects and most Gi α 1 are not phosphorylated and thus remain functional¹⁶.

[0011] The assessment of an imbalance between Gi and Gs coupled receptor signaling (as opposed to the assessment of a Gi-coupled receptor signaling impairment), greatly simplifies the risk assessment and endophenotype (functional group) assessment by eliminating the need of a reference signal from a control subject (see for example co-pending PCT application PCT/CA2014/050562, and co-pending US application No. 61/875,162 to Moreau). The establishment of a reference signal is often difficult and may sometimes constitute an obstacle because the control subject(s) from whom the reference signal is derived should preferably match with age, gender, and medication, if any. Life-style (e.g., exercises and food) may also have some influence on the level of impairment, scoliosis marker level and individual cellular responses.

[0012] Finally, in copending US application No. 61/875,162, Applicants further describe novel alternative methods of identifying subjects at risk of developing IS and of classifying IS subjects into a specific IS functional group. These methods improve current classification methods by providing distinct (unique) cellular responses for the specific functional groups thereby enabling to classify borderline subjects, which may not otherwise be identified as belonging to a specific functional group with sufficient confidence (high specificity) using other known methods.

[0013] In particular, Applicants have demonstrated that borderline subjects which cannot be unambiguously classified into a particular endophenotype subgroup using one or more of the above methods can be distinguished by assessing the effect of osteopontin (OPN) on the cellular response following Gi-stimulation (see co-pending US application No. 61/875,162). Hence, subjects having a scoliosis or at risk of developing scoliosis can be identified by detecting an impairment in their cellular response following Gi stimulation and classified according to their Gi functional status (FG1, FG2 and FG3) without ambiguity.

[0014] A second method disclosed therein takes advantage of unique cellular impedance profiles following Gi-protein stimulation in four GiPCR clusters (I, II, III and IV). The impedance profile for each cluster has a different shape. In addition, in the case of GiPCR cluster II, only FG1 subject show an impedance profile comprising a characteristic negative impedance phase followed by a positive phase, thereby enabling to easily distinguish FG1 subjects from FG2 and FG3 subjects. Finally, a third classification method is based on the demonstration that FG1 subjects can further be distinguished over FG2 and FG3 subjects based on their cellular response to GiPCR cluster I and/or II stimulation in the presence of high concentration of PTX. Following GiPCR cluster I or cluster II agonist stimulation, the cellular response curve in the presence of PTX is characterized by a first phase in which the response decreases with increasing amounts of PTX followed by a second phase where the response increases with increasing amounts of PTX (V shape curve). In the second phase of the response, the % of response relative to administration of a control vehicle is above that of the corresponding % of response for control (subjects not having IS or not at risk of developing IS), FG2 and FG3 subjects. Hence, a magnitude of cellular response in the presence of high concentration of PTX that is above that of a control (subjects not having IS or not at risk of developing IS as well as FG2 and FG3 subjects) indicates that the subjects belongs to the FG1 functional group.

[0015] Once diagnosed, the primary concern for physicians in managing scoliotic children is whether the curve will progress. Indeed, the curve progression is often unpredictable and is more frequently observed among girls than in boys ¹². If untreated, the curve can progress dramatically, creating significant physical deformity and even cardiopulmonary problems. These manifestations become life threatening when the curve exceeds 70 degrees ^{13,14}. The current treatment options to prevent or stop curve progression include bracing and surgery. In general, bracing is recommended for curves between 25 and 40 degrees, while surgery is reserved for curve greater than 45 degrees or curves that are unresponsive to bracing.

[0016] All diagnosed IS children are subjected to multiple radiographs over several years, usually until they reach skeletal maturity. Patients with a curve that is between 20 to 30 degrees will usually be observed at 4 to 6 month intervals with an x-ray test to measure the curve. Any progression that is less than 5 degrees is not considered significant. If the curve progresses more than 5 degrees, then the curve will need treatment. In general, treatment with a back brace will be recommended for patients: i) having a curve of about 25 to 40 degrees, and; ii) who are still growing i.e. patients who are skeletally immature (e.g., girls who are about 11 to 13 years old, and boys who are about 12 to 14 years, Risser between 0 and 3). Brace treatment is typically used in girls up to one/-two years after

menarche, the onset of the female menstrual cycle. Brace treatment will often be maintained after menarche until curve progression has stabilized for 1-2 years, but may be stopped when skeletal maturity is reached. If an older child has a curve greater than 30 degrees and is almost mature (Risser of 4-5), his or her curvature will often be treated with observation only, as there is little growth left and bracing is unlikely to be as effective. The only curves that tend to progress after skeletal maturity are those that are greater than 50 degrees in angulation, so the treatment objective with the back brace is to try to bring the child into adulthood with less than a 50 degree curvature.

[0017] Typically, if the curve continues to progress to 40-45 degrees or more, a spinal fusion surgery will usually be recommended. However, even if surgery eventually becomes necessary, the back brace can still be beneficial by helping delay the progression of the curvature and allowing optimal growth for the child before undergoing spinal fusion (which ends the spine growth).

[0018] Unfortunately, some patients do not respond or respond poorly to bracing, and their spinal curves continue to progress. Currently, there is no approved method or test available to predict which affected individuals are likely to benefit from bracing and which individuals are likely to experience a curve progression requiring surgery, despite brace treatment.

[0019] It would be advantageous to identify prior to treatment subjects likely to benefit from brace treatment (or other scoliosis treatment) from those unlikely to benefit from it or likely to worsen following treatment. Curves that progress can require fusion surgery and/or lead to potential long-term health problems. Even for patients unlikely to worsen after brace treatment, it would be advantageous to avoid the treatment if it is unnecessary or ineffective: while it is non-invasive, bracing for scoliosis is in itself a very difficult treatment option for many patients and may have a significant psychological impact. Early knowledge of bracing treatment outcome could therefore help IS treatment by avoiding unnecessary bracing and by enabling the selection of the most appropriate treatment for a given individual early on during the course of the disease.

[0020] The present description refers to a number of documents, the content of which is herein incorporated by reference in their entirety.

SUMMARY OF THE INVENTION

[0021] Mechanotransduction (biomechanics and bodily responses to mechanical stimuli) is involved in IS development as well as its non-surgical treatments (i.e. bracing, physical therapies). Mechanotransduction is a relatively new and emerging angle of research in the field of IS (e.g., AIS) study that holds many possibilities for novel personalized therapeutic options. Knowledge of the specific genes and biochemical pathways that are altered because of mechanotransduction differences in scoliosis could significantly change the diagnosis and treatment of IS.

[0022] In this context, the present invention identified that certain mechanotransductive genes (e.g., SSP1 encoding OPN; SPP1- Gene ID: 6696, OPNa: NP_001035147.1, OPNb: NP_000573.1, OPNc: NP_001035149.1, OPN Isoform 4: NP_001238758.1, OPN Isoform 5: NP_001238759.1, NM_001251829.1, GI_352962173) and pathways are distinctive between FG1 and the two other IS functional groups (FG2 and FG3). The present invention is based in part on the discovery that depending on their Gi functional status (FG1, FG2 or FG3), subjects suffering from IS do not equally respond to bracing and OPN.

[0023] The present inventors have found that subjects of the FG3 functional group are more likely than those of the FG2 functional group to have successful brace treatment, while subjects belonging to the FG1 group are the least likely to have successful brace treatment and their condition could even be aggravated by brace treatment. They have also found that OPN has a protective effect in subjects belonging to the FG1 functional group while it is a risk factor in the subjects of the FG2 and FG3 functional groups. Indeed, it was unexpectedly found that OPN increases the Gi-mediated response in FG1 subjects while it further decreases (aggravates) the impairment observed in the Gi-mediated response of FG2 and FG3 functional groups. This illustrates the heterogeneity of mechanical response on a biological level among IS patients and could explain why some patients are considered as brace-responders while for others, bracing cannot stop curve progression.

[0024] Accordingly, the present invention provides a method of predicting brace treatment outcome in a subject in need thereof comprising classifying the subject into functional group FG1, FG2 or FG3, wherein the classification enables the prediction of brace treatment outcome.

[0025] In a specific embodiment, the classification of the subject into the FG2 or FG3 functional group is indicative that the subject is likely to benefit from brace treatment. In another specific embodiment, the classification of the subject into the FG1 functional group is indicative that the subject is unlikely to benefit from brace treatment. In another specific embodiment, the classification of the

subject into the FG2 or FG3 functional group is indicative that the subject is likely to have a successful brace treatment. In another specific embodiment, the classification of the subject into the FG1 functional group is indicative that the subject is unlikely to have a successful brace treatment. In another specific embodiment, the classification of the subject into the FG2 or FG3 functional group is indicative that the subject has a decreased risk of curve progression following brace treatment. In another specific embodiment, the classification of the subject into the FG1 functional group is indicative that the subject has an increased risk of curve progression following brace treatment. In another specific embodiment, the classification of the subject into the FG2 or FG3 functional group is indicative that the subject has a decreased risk of requiring surgery following brace treatment. In another specific embodiment, the classification of the subject into the FG1 functional group is indicative that the subject has an increased risk of requiring surgery following brace treatment. In another specific embodiment, the method further comprises measuring the level of OPN in a blood sample from the subject prior to the beginning of brace treatment. In another specific embodiment, the classification of the subject into the FG1 functional group and a high level of OPN in the blood sample from the subject is indicative that the subject is further unlikely to benefit from brace treatment. In another specific embodiment, the classification of the subject into the FG1 functional group and a low level of OPN level in the blood sample from the subject is indicative that the subject may benefit from a short brace treatment. In another specific embodiment, the classification of the subject into the FG2 or FG3 functional group and a high level of OPN in the blood sample from the subject is indicative that the subject is further likely to benefit from brace treatment.

[0026] In another specific embodiment, the brace treatment comprises treatment with a Thoraco-Lumbo-Sacral-Orthosis (TLSO) brace, a Milwaukee brace, a Charleston brace, a SpineCor™ brace or any combination thereof. In another specific embodiment, the brace treatment comprises treatment with a Thoraco-Lumbo-Sacral-Orthosis (TLSO) brace.

[0027] In accordance with another aspect of the present invention, there is provided a method of predicting the risk of developing idiopathic scoliosis in a subject in need thereof comprising: classifying the subject into functional group FG1, FG2 or FG3; measuring the level of OPN in a blood sample from the subject, wherein a classification of the subject into the FG1 functional group and a low level of OPN or a classification of the subject into the FG2 or FG3 functional group and a high level of OPN is indicative that the subject has an increased risk of developing idiopathic scoliosis. In a specific embodiment, the risk of developing scoliosis is a risk of curve progression.

[0028] In accordance with yet another aspect of the present invention, there is provided a

method of treating a subject suffering from an idiopathic scoliosis or at risk of developing an idiopathic scoliosis comprising classifying the subject into functional group FG1, FG2 or FG3, wherein when the subject is classified into the FG1 functional group, the subject is not treated with a brace; and when the subject is classified into the FG2 or FG3 functional group, the subject is treated with a brace.

[0029] In accordance with yet another aspect of the present invention, there is provided a method of treating a subject in need thereof comprising classifying the subject into functional group FG1, FG2 or FG3, wherein when the subject is classified into the FG1 functional group, the subject is treated with OPN or an OPN agonist or with treatment or preventive measures which increase the level or activity of circulating OPN; and when the subject is classified into the FG2 or FG3 functional group, the subject is treated with an OPN antagonist or with treatment or preventive measures which decrease the level or activity of circulating OPN.

[0030] In accordance with yet another aspect of the present invention, there is provided a method of treating a subject in need thereof comprising a) classifying the subject into functional group FG1, FG2 or FG3; and b) determining the level of OPN in a blood sample from the subject, wherein when the subject is classified into the FG1 functional group and the level of OPN is high, the subject is not treated with a brace; when the subject is classified into the FG1 functional group and the level of OPN is low, the subject is optionally treated with a brace for a short period of time; and when the subject is classified into the FG2 or FG3 functional group the subject is treated with a brace.

[0031] In a specific embodiment, when the subject is classified into functional group FG1, the subject is further treated with OPN or an OPN agonist or with treatment or preventive measures which increase the level or activity of circulating OPN. In another specific embodiment, when the subject is classified into functional group FG2 or FG3, the subject is further treated with an OPN antagonist or with treatment or preventive measures which decrease the level or activity of circulating OPN.

[0032] In a related aspect, the present invention provides a method of treating a subject in need thereof comprising classifying the subject into functional group FG1, FG2 or FG3, wherein (i) when the subject is classified into the FG1 functional group, the level of OPN or the activity of OPN in said subject is increased; and (ii) when the subject is classified into the FG2 or FG3 functional group, the level of OPN or the activity of OPN in said subject is decreased. In an embodiment, i) comprises treating said subject with: (a) OPN; (b) an OPN agonist; (c) a treatment or preventive measure which increases the level of circulating OPN; (d) an inhibitor of CD44 expression or activity; or (e) a combination of at least two of (a) to (d). In an embodiment, ii) comprises treating said subject with: (f) an

OPN antagonist; (g) a treatment or preventive measure which decreases the level of circulating OPN; (h) an inhibitor of integrin expression or activity; (i) sCD44 or a stimulator of CD44 expression; or (j) a combination of at least two of (f) to (i).

[0033] In an embodiment, the OPN agonist is (b i) HA; (b ii) an OPN functional fragment; (b iii) an OPN functional derivative; or (b iv) a combination of at least two of (b i) to (b iii). In an embodiment the treatment or preventive measure which increases the level of circulating OPN comprises applying pulsative compressive pressure for 15-90 minutes on at least one body part of said subject. In an embodiment the treatment or preventive measure which increases the level of circulating OPN comprises applying low intensity pulse ultrasound (LIPUS). In an embodiment the inhibitor of CD44 expression or activity is an antibody which binds to CD44 or a siRNA or antisense specific for CD44. In an embodiment the OPN antagonist is (f i) melatonin; (f ii) selenium; (f iii) an antibody which binds to OPN; (f iv) an siRNA or antisense specific for OPN; (f v) a molecule that blocks the binding of OPN to integrins; or (f vi) a combination of at least two of (f i) to (f vi). In an embodiment the treatment or preventive measure which decreases the level of circulating OPN is: (g i) brace treatment; (g ii) accupoint heat sensitive moxibustion; (g iii) heat therapy with pad; (g iv) electroacupuncture; (g v) thermal bath; or (g vi) a combination of at least two of (g i) to (g v). In an embodiment the molecule that blocks the binding of OPN to integrins is a RGD peptide or derivative thereof. In an embodiment the molecule that blocks the binding of OPN to integrins is a peptide fragment of OPN comprising a RGD motif. In an embodiment the peptide fragment of OPN comprises the amino acid sequence GRGDSVYGLRS (SEQ ID NO: 13). In an embodiment the inhibitor of integrin activity is (h i) an antibody that binds specifically to integrin subunit α_5 ; (h ii) an antibody that binds specifically to integrin subunit β_1 ; (h iii) an antibody that binds specifically to integrin subunit β_3 ; (h iv) an antibody that binds specifically to integrin subunit β_5 ; (h v) an antibody that binds specifically to integrin subunits $\alpha_5\beta_1$; or (h vi) a combination of at least two of (h i) to (h v). In an embodiment the inhibitor of integrin activity is volociximabTM; ATN-161, etaratuzumabTM, etaracizzumabTM, VitaxinTM, MEDI-522, CNT095 or CilengitideTM. In a particular embodiment the inhibitor of integrin activity is volociximabTM or CilengitideTM. In a particular embodiment of the methods of the present invention, integrin is $\alpha_5\beta_1$. In an embodiment, the inhibitor of integrin expression is (h i) an siRNA or antisense specific to integrin subunit α_5 ; (h ii) an siRNA or antisense specific to integrin subunit β_1 ; (h iii) an siRNA or antisense specific to integrin subunit β_3 ; (h iv) an siRNA or antisense specific to integrin subunit β_5 ; (v) a combination of at least two of (h i) to (h vi).

[0034] In a particular aspect, the above treatment methods further comprise treating the subject with a brace.

[0035] In another specific embodiment, the above methods of the present invention further comprise measuring the level of OPN in a blood sample from the subject periodically. In another specific embodiment, the level of OPN is measured once a month.

[0036] In another specific embodiment, the high level of OPN in the blood sample of the subject is between about 600-1000 ng/ml. In another specific embodiment, the low level of OPN in the blood sample of the subject is ≤ 500 ng/ml.

[0037] In another specific embodiment, the subject is a pediatric subject.

[0038] In another specific embodiment, the classification comprises determining changes in cellular impedance following Gi-stimulation in a cell sample from the subject. In another specific embodiment, the cellular impedance is measured by cellular dielectric spectroscopy (CDS). In another specific embodiment, the classification comprises measuring changes in cAMP concentration following Gi-stimulation in a cell sample from the subject. In another specific embodiment, the classification comprises determining the phosphorylation pattern of G α proteins in a cell sample from the subject. In another specific embodiment, the classification comprises determining cellular proliferation of a cell sample from the subject.

[0039] In another specific embodiment, the subject is a subject diagnosed with Idiopathic Scoliosis (IS). In another specific embodiment, the Idiopathic Scoliosis is Adolescent Idiopathic Scoliosis (AIS).

[0040] In accordance with another aspect of the present invention, there is provided a kit for predicting brace treatment outcome in a subject suffering from Idiopathic Scoliosis or for predicting the risk of developing severe Idiopathic Scoliosis comprising reagents for classifying a subject into functional group FG1, FG2 or FG3. In a specific embodiment of the kit, the kit comprises at least two of (i) a ligand for Gi stimulation; (ii) a ligand for detecting G α proteins phosphorylation; and/or (iii) reagents for detecting cellular proliferation. In a specific embodiment of the kit, the kit further comprises: (i) a ligand for Gs stimulation; (ii) reagents for detecting the level of OPN; and/or (iii) instructions for predicting brace treatment outcome.

[0041] Other objects, advantages and features of the present invention will become more apparent upon reading of the following non-restrictive description of specific embodiments thereof, given by way of example only with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] In the appended drawings:

[0043] Figure 1 presents possible treatment options depending on the functional status of the subject and the level of circulating OPN in the blood sample of the subject. A. Brace treatment options depending on the subject's functional group and on the circulating level of OPN. B. Complementary/alternative treatment options according to the functional status of the subject;

[0044] Figure 2 shows OPN circulating levels between age 9 and 18 in controls and AIS subjects;

[0045] Figure 3 shows OPN circulating levels variation in blood sample of AIS subjects during brace treatment. Figure 3A shows OPN circulating levels variation in blood samples of AIS subjects having low initial OPN circulating levels (e.g., below about 600ng/ml) and Figure 3B shows OPN circulating levels variation in blood samples of AIS subjects having high initial OPN circulating levels (e.g., at or above about 600ng/ml);

[0046] Figure 4 shows curve progression and subject's clinical information (A) and OPN and sCD44 levels variation (B) with time in blood samples from a female FG1 AIS subject (#593);

[0047] Figure 5 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a female FG1 AIS subject (#148);

[0048] Figure 6 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a male FG1 AIS subject (#393);

[0049] Figure 7 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a male FG1 AIS subject (#498);

[0050] Figure 8 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a female FG1 AIS subject (#530);

[0051] Figure 9 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a female FG1 AIS subject (#627);

[0052] Figure 10 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a female FG1 AIS subject (#675);

[0053] Figure 11 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a female FG1 AIS subject (#394);

[0054] Figure 12 shows curve progression and subject's clinical information (A) and OPN and sCD44 levels variation (B) with time in blood samples from a female FG1 AIS subject (#679);

[0055] Figure 13 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a female FG1 AIS subject (#460);

[0056] Figure 14 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a female FG1 AIS subject (#789);

[0057] Figure 15 shows OPN and sCD44 levels variation (A); and curve progression and subject's clinical information (B) with time in blood samples from a female FG1 AIS subject (#144);

[0058] Figure 16 shows curve progression and subject's clinical information (A) and OPN and sCD44 levels variation (B) with time in blood samples from a female FG2 AIS subject (#208);

[0059] Figure 17 shows curve progression and subject's clinical information (A) and OPN and sCD44 levels variation (B) with time in blood samples from a female FG2 AIS subject (#159);

[0060] Figure 18 shows curve progression and subject's clinical information (A) and OPN and sCD44 levels variation (B) with time in blood samples from a female FG2 AIS subject (#272);

[0061] Figure 19 shows curve progression and subject's clinical information (A) and OPN and sCD44 levels variation (B) with time in blood samples from a female FG3 AIS subject (#301);

[0062] Figure 20 shows that cell response to OPN is genetically programmed in AIS patients. Gi-mediated cellular response in the presence of increasing amounts of rOPN was measured by cellular impedance using the CellKey™ system (Akoume et al., 2010; and Akoume et al., 2013 (J. Vis. Exp.)) in functional groups FG1, FG2 and FG3;

[0063] Figure 21 shows that knock down of OPN rescued Gi-mediated cell signalling in AIS subjects of FG2 and FG3 functional groups. Gi-mediated cellular response in the presence siRNAs against rOPN was measured by cellular impedance using the CellKey™ system (Akoume et al., 2010; and Akoume et al., 2013 (J. Vis. Exp.)) in functional groups FG1, FG2 and FG3;

[0064] Figure 22 shows the effect of OPN and hyaluronic acid treatment on GiPCR signaling in

cells of healthy and AIS subjects according to their biological endophenotype. Osteoblasts from healthy subjects and AIS patients of each endophenotype (FG1, FG2 and FG3) were treated with vehicle, OPN (500ng/ml) or HA (10 μ M). The Gi-mediated cellular response in the presence of increasing amounts of LPA was measured by cellular impedance using the CellKey™ system;

[0065] Figure 23 shows that absence or inhibition of CD44 potentiates the effects of OPN on Gi-mediated cell signaling in each biological endophenotype groups (FG1, FG2 and FG3). CD44 activity (A) or expression (B) was inhibited in osteoblasts from control, FG1, FG2 and FG3 patients and the effect on OPN-dependent inhibition of Gi-mediated cell signaling was monitored using the CellKey™ system following stimulation with LPA. Inhibition of CD44 using an anti-CD44 antibody (A) or a siRNA against CD44 (B) further decreased Gi-mediated cell signaling in control, FG2 and FG3 subjects while it further increased Gi-mediated cell signaling in FG1 subjects;

[0066] Figure 24 shows that OPN-dependent inhibition of Gi-mediated cell signaling involves integrins. Antibodies against integrins β_1 , β_3 and β_5 reverse the effect of OPN on Gi-mediated response in FG2 and FG3 subjects only, while blockade of CD44 further potentiates the effect of OPN. (A,C,D) In osteoblasts from control, FG2 and FG3 subjects, the inhibition of OPN on Gi-mediated cell signaling can be reversed by antibodies against integrins β_1 , β_3 and β_5 while inhibition of CD44 using an anti-CD44 antibody further reduced (aggravated) Gi-mediated signaling in FG2 and FG3 subjects and potentiated the effect of OPN. Inhibition of integrin β_1 was most effective; (B) In osteoblasts from FG1 subjects antibodies against integrins β_1 , β_3 and β_5 have an opposite effect and reduced (blocked) the increase in Gi-mediated response induced by OPN, although to a lesser extent. Conversely, inhibition of CD44 using a CD44 antibody, increased the Gi-mediated response in FG1 subjects; and

[0067] Figure 25 shows that OPN-dependent inhibition of Gi-mediated cell signaling involves integrins. SiRNAs against integrins β_1 , β_3 and β_5 reversed the effect of OPN on Gi-mediated response while blockade of CD44 further potentiates the effect of OPN. (A, C,D) In osteoblasts from control, FG2 and FG3 subjects, the inhibition of OPN on Gi-mediated cell signaling can be reversed by siRNAs against integrins β_1 , β_3 and β_5 while inhibition of CD44 using an siRNA further reduced Gi-mediated signaling and potentiated the effect of OPN (B) In osteoblasts from FG1 subjects, siRNAs against integrins β_1 , β_3 and β_5 had an opposite effect and reduced (blocked) the increase in Gi-mediated response induced by OPN but in a less or non-significant extent.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0068] Applicants have assessed whether circulating OPN levels have the same effect with

regards to Gi-mediated response and risk of developing scoliosis among the three functional groups and have undertaken a retrospective study with IS subjects to determine whether patient bracing outcome could be differentiated based on their Gi functional status (FG1, FG2 and FG3).

[0069] The present invention is based on the findings that i) OPN has a differential (opposite) effect on the response to Gi stimulation among IS functional groups (it decreases the Gi-mediated response in control, FG2 and FG3 subjects while it increases the Gi-mediated cellular response in FG1 subjects); ii) inhibition of the expression or activity of CD44 (a receptor for OPN) potentiates the effect of OPN; iii) Hyaluronic acid (HA) (which binds to CD44 receptor with higher affinity than OPN) also has a differential effect on Gi-mediated cellular response (it decreases the Gi-mediated response in control, FG2 and FG3 subjects while it increases the Gi-mediated cellular response in FG1 subjects; iv) inhibition of the expression or activity of integrins (which bind OPN) reduce the effect of OPN on the Gi-mediated cellular response in FG2 and FG3 subjects; v) high circulating OPN level in FG1 subjects has a protective effect while it is a risk factor in FG2 and FG3 subjects; vi) brace treatment outcome is most favorable in FG2 and FG3 subjects (mainly in FG3); vii) bracing is less effective in FG1 subjects with significant increased likelihood to progress over 45° and to have surgery than the other 2 groups; and viii) bracing generally decreases circulating OPN levels in all AIS subjects. Taken together, these results enable to improve IS treatment, to more accurately predict brace treatment outcome and to select the most appropriate treatment method and follow up schedule for each patients according to their biological endophenotype (FG1, FG2 and FG3) and/or circulating OPN level.

[0070] IS patient bracing outcome was evaluated in regard to curve progression leading up to surgery between the 3 functional groups (FG1, FG2 and FG3). Each patient had been previously classified in one of the 3 functional groups (FG1, FG2 or FG3) using a cell-based assay measuring cAMP (Moreau et al., 2004) variation and/or CDS response (Akoume et al., 2010) following Gi stimulation. Outcome of brace treatment in terms of curve progression over 45° and occurrence of corrective surgery was determined for each functional group. It was found that bracing is less effective in FG1, with an increased likelihood to progress over 45° and to have surgery than the other 2 groups. Outcomes of bracing were most favorable for patients presenting the FG3 endophenotype.

[0071] Applicants have determined that subjects classified in the FG1 functional group are less likely to benefit from bracing. Furthermore, FG1 subjects having high level of OPN (e.g., above 1000ng/ml) are less likely to progress than FG1 subjects having low levels of OPN ($\leq$ 500 ng/ml).

Results suggest that in FG1 subjects, when the level of OPN decreases around 500ng/ml or below, scoliosis tend to progress (i.e., increase in Cobb's angle). These results are consistent with applicant's findings that in the FG1 functional group, OPN reduces the Gi-mediated signaling defect (i.e., increases Gi-mediated cell signaling) generally present in scoliosis subjects. Applicants have also determined that brace treatment generally decreases OPN levels by way of a retroinhibition mechanism and that effect of brace treatment may further be distinguished based on initial circulating OPN levels prior to beginning of treatment. Indeed, it was found that in certain subjects having initial low level of circulating OPN, brace treatment first induces a sharp rise in OPN levels (within the first 6 months) while it induces a sharp decrease in OPN levels in subjects having high initial OPN levels, thereby supporting a retroinhibition mechanism controlling circulating OPN levels *in vivo*. Furthermore, Applicants have found that high circulating OPN levels have a protective effect on patients of functional group FG1 and have a detrimental effect (i.e., increasing their risk of developing a scoliosis) in subjects classified into the FG2 and FG3 functional groups.

[0072] Accordingly, FG1 subjects (especially having a high level of circulating OPN) should generally not be prescribed brace treatment even if very short. Subjects of the FG2 and FG3 functional groups are more likely to benefit from brace treatment (e.g., long term brace treatment) possibly because it generally decreases OPN levels and an elevated OPN level is a risk factor for these subjects.

[0073] Hence, further combining endophenotype classification with OPN circulating levels allows to further distinguish among functional groups which subjects should be treated with a brace, which subjects should have their level or activity of OPN lowered (e.g., FG2 and FG3 subjects), which subject should have their level or activity of OPN increased (FG1 subjects), which subjects should have their level of CD44 (e.g., sCD44) increased (FG2 and FG3); which subjects should have their level of CD44 (e.g., sCD44) decreased (e.g., FG1); which subjects should have their level of HA increased (FG1); which subjects should have their level of HA decreased (FG2 and FG3); which subjects should have their level or activity of integrins (e.g., α_5 , β_1 , β_3 and β_5) decreased (FG2 and FG3); as well as the optimal duration of treatment. Other treatment regimens known to have an effect on OPN, HA, CD44 or integrins level or activity may also be adapted according to each specific functional group (e.g., specific exercises or massages (e.g., application of compressive pressure for 15 to 90 minutes- See for example US 13/822,982, and low intensity pulsed ultrasounds (LIPUS), for FG1 patients, because such approaches can increase OPN expression level (e.g., OPN plasma level)), accupoint heat sensitive moxibustion or heat therapy with pad, thermal bath, electroacupuncture (for FG2 and FG3 subjects

because such approaches are known to decrease OPN levels in serum of subjects). These findings enable personalized treatment prescription according to each patient Gi- endophenotype and/or OPN level, early on following diagnosis thereby avoiding unnecessary delay in finding best treatment options which will ultimately improve IS treatment outcome.

[0074] Accordingly, the present invention provides a method of predicting brace treatment outcome in a subject in need thereof comprising; i) classifying the subject into functional group FG1, FG2 or FG3, wherein the classification enables the prediction of brace treatment outcome.

[0075] Specifically, according to the above method, classification of the subject into the FG1 functional group is indicative that the subject: i) is less likely to benefit from brace treatment (e.g., is less likely to have brace treatment success); ii) is more likely to require surgery; iii) is more likely to show a curve progression $> 6^\circ$ in Cobb's angle; iv) is less likely to have a Cobb angle $\leq$ to 45° ; and v) is more likely to aggravate his/her condition (e.g., increase speed of curve progression or increased final Cobb angle) by brace treatment as compared to FG2 and FG3 functional groups.

[0076] According to the above brace treatment outcome prediction method, classification of the subject into the FG3 functional group is indicative that the subject: i) is more likely to benefit from brace treatment (e.g., is more likely to have brace treatment success); ii) is less likely to require surgery; iii) is less likely to show a curve progression $> 6^\circ$ in Cobb's angle; iv) is more likely to have a Cobb angle $\leq$ to 45° ; and v) that the subject is less likely (or unlikely) to aggravate his/her condition (e.g., increase speed of curve progression or increased final Cobb angle) by brace treatment as compared to FG1 and FG2 functional groups.

[0077] Finally, classification of the subject into the FG2 functional group according to the above brace treatment outcome prediction method is indicative that the subject: i) has moderate chances of benefiting from brace treatment (e.g., the subject has moderate chances of brace treatment success); ii) has moderate risk of requiring surgery; iii) has moderate risk to show a curve progression $> 6^\circ$ in Cobb's angle; iv) has moderate risk of having a Cobb angle $\leq$ to 45° ; and v) has low risk of aggravating his/her condition (e.g., increase speed of curve progression or increased final Cobb angle) by brace treatment as compared to FG1 and FG3 functional groups.

[0078] Under certain circumstances, certain rare FG1 subjects could nevertheless benefit from a

short brace treatment if, in such patients bracing increases OPN level. It was found that subjects in each functional group may further be distinguished based on their level of circulating OPN (low or high level of OPN). In order to further distinguish among each groups which subjects could benefit from brace treatment, the present prediction method can advantageously further comprise measuring the level of circulating OPN prior to the beginning of brace treatment. According to this method, certain subjects classified into the FG1 functional group and having a low level of circulating OPN (e.g., below 500 ng/ml) may benefit from a short brace treatment (e.g., 6 months or less) and are less likely to aggravate their condition by short treatment than FG1 subjects having high levels of circulating OPN because brace treatment can induce an increase in circulating OPN in these subjects at the beginning of treatment and OPN has a protective effect in these subjects. The short brace treatment may be for 18 months or less, preferably 12 months or less and more preferably, 6 months or less or until OPN concentration is at its maximal concentration or close to its maximal concentration (i.e., below the retroinhibition concentration). It should be noted that if an FG1 subject is treated with a brace, his/her OPN level should be monitored closely in order to detect any drop in circulating OPN. Preferably, brace treatment would be pursued only if and while bracing induces an increase in OPN level. If a drop in circulating OPN level is detected, then brace treatment should be stopped.

[0079] According to the above method, subjects classified into the FG2 or FG3 functional group and having a high level of circulating OPN may more rapidly benefit from brace treatment than FG2 or FG3 subjects having low levels of circulating OPN because OPN is a risk factor in these subjects and brace treatment reduces the level of circulating OPN in these subjects. In subjects of the FG2 and FG3 functional groups having a low level of circulating OPN, brace treatment is nevertheless beneficial but is preferably maintained for a sufficient time so that the level of OPN level is decreased (e.g., 12-18 months and preferably more than 18 months).

[0080] In a related aspect, the present invention also encompasses selecting the most efficient and least invasive known preventive action, treatment or follow-up schedule in view of the determined classification and concentration of circulating OPN level.

[0081] Accordingly, the present invention provides a method of treating or preventing IS in a subject comprising, classifying the subject into functional group FG1, FG2 or FG3, wherein when the subject is classified into the FG1 functional group: i) the subject is treated with OPN; ii) the subject is treated with an OPN agonist (e.g., HA supplements or treatment or preventive measures which increase HA level such as a HA rich diet) ; iii) the subject is treated with a CD44 antagonist (e.g., an antibody

against CD44); iv) the subject is treated with an integrin agonist (or the subject is prescribed treatment or preventive measures which increase integrin level or activity); iv) the subject is prescribed treatment or preventive measures which increase circulating OPN levels (e.g., massages such as by compressive pressure as described in US 13/822,982; low intensity pulsed ultrasound (LIPUS), etc.); v) the subject is prescribed treatment or preventive measures which decrease CD44 level or activity (e.g., siRNA specific for CD44 or antibody which blocks CD44 binding to OPN); ; and vi) any combinations of i) to v); and wherein when the subject is classified into functional group FG2 or FG3, the subject is vii) treated with an OPN antagonist (e.g., OPN antibody, OPN siRNA, melatonin, vitamin D, PROTANDIM™ (nutraceutical cocktail known to reduce plasma or serum OPN levels and used as a natural anti-oxydant mix), an inactive OPN derivative or analog blocking one or more OPN receptors (e.g., $\alpha_5\beta_1$, $\alpha_4\beta_1$, $\alpha_9\beta_1$, and $\alpha_9\beta_4$)); viii) the subject is treated with sCD44 or a CD44 agonist; ix) the subject is treated with an integrin antagonist (e.g., RGD peptide or derivative thereof, a synthetic peptide acting as specific α_v integrin inhibitor (e.g. cilengitide™) or monoclonal antibodies targeting specifically integrin (volociximab™ ($\alpha_5\beta_1$); etaratuzumab™ ($\alpha_v\beta_3$), etaracizzumab™ ($\alpha_v\beta_3$), vitaxin ($\alpha_v\beta_3$), MEDI-522 ($\alpha_v\beta_3$)) or anti- α_v integrin (CNT095); or x is prescribed treatment or preventive measures which reduce the level of circulating OPN (e.g., brace treatment, accupoint heat sensitive moxibustion, heat therapy with pad, thermal bath, electroacupuncture, etc.); xi) the subject is prescribed treatment or preventive measures which increase CD44/sCD44 level; xii) the subject is prescribed treatment or preventive measures which decrease HA level (e.g., HA-poor diet); xiii) the subject is prescribed an integrin antagonist (e.g., an antibody or siRNA specific for integrin α_5 , β_1 , β_3 or β_5 or treatment or preventive measures which decrease integrin level or activity); and xiv) any combinations of vii) to xiii);. In addition to the above, non-limiting treatments or preventive measures include: exercises (physiotherapy), orthodontic treatment, and administration of other natural substances increasing or reducing OPN, CD44 and HA levels. Once a subject is classified into a specific functional group, his/her OPN levels are preferably monitored periodically. When a new treatment or preventive measure is prescribed OPN levels should be monitored in order to maintain the optimal level of OPN (e.g., below or above the OPN retroinhibition/retroactivation concentrations) for this subject and detect any variation that could potentially accelerate the development of IS (including curve progression).

[0082] Accordingly, the above treatment or prevention method may further be improved by measuring the level of circulating OPN in the subject and determining whether the subject has a high or low level of circulating OPN. Determination of the level of circulating OPN (and of its variation with time) enables to more appropriately select the best treatment option and follow-up schedule. Figure 1 summarizes treatment options in view of the functional status of the subject and his/her level of

circulating OPN.

[0083] For example, an FG1 subject could be prescribed OPN or an OPN agonist. For FG1 subjects, brace treatment should generally be avoided. However, FG1 subjects having low levels of circulating OPN could under specific circumstances be prescribed brace treatment for a short period of time (e.g., about 6 months or until OPN concentration has been sufficiently increased i.e., at or near the retroinhibition concentration) so as to maintain his/her level of OPN high. Brace treatment could be stopped completely or temporarily when the maximal concentration of OPN is reached (i.e., near (but below) the retroinhibition concentration for a given patient e.g., for example between about 600 ng/ml and 1200 ng/ml, preferably between about 600ng/ml and 1000 ng/ml. Generally, for FG1 subjects, preventive and treatment measures should aim at maintaining their level of OPN as high as possible.

[0084] For FG1 subjects already having high levels of OPN (i.e., close to the maximal OPN concentration where retroinhibition is induced), brace treatment should be avoided. If brace treatment is nevertheless prescribed, OPN levels and curve progression should be monitored closely so as to make sure that OPN levels do not drop significantly and that the rate or curve progression is not increased. OPN or an OPN agonist could also be prescribed to maintain OPN concentration high (as OPN has a protective effect in FG1 subjects as indicated above).

[0085] In general, any treatment or preventive measure which will help maintaining the level or activity of OPN as high as possible is desirable for FG1 subjects. In an embodiment, massages which increase OPN's level can be performed on a regular basis. For example, in US 13/822,962 Applicants show that the local application of pressure (e.g., pulsative compressive pressure) on at least one body part of the subject (e.g., arm or leg) for 15-90 minutes increases circulating OPN blood level. Hence, such treatment could be applied to the subject periodically (e.g., every day, every two days, every 3 days, twice a week, once a week or once every two weeks) to increase or maintain the level of circulating OPN. Furthermore, as disclosed herein, HA increases (i.e., compensate in part) the Gi-mediated signaling defect present in FG1 subjects. Without being bound to any particular theory, HA could act by increasing OPN's bioavailability by competing with OPN for binding to CD44 (and thus act as an OPN agonist). By doing so, more OPN could be available for increasing the Gi-mediated cellular response.

[0086] Accordingly, one way of increasing the level or desired activity of OPN is by increasing the amount of Hyaluronic Acid (HA) in subjects. This can be done for example by taking HA supplements or by increasing HA intake or HA synthesis by favoring certain food. Non-limiting examples

of food with high HA content or which stimulates/support HA production include, meat and meat organs (e.g., veal, lamb, beef and gizzards, livers, hearts and kidneys), fish, poultry (including meat fish and poultry broths), soy (including soy milk), root vegetables containing starch including potatoes and sweet potatoes, satoimo (Japanese sweet potato), imoji (Japanese sweet potato), Konyaku concoction (root vegetable concoction). Fruits and vegetables rich in vitamin C, magnesium or zinc are also useful as they support the synthesis of HA by the body. Non-limiting examples of food rich in vitamin C include lemons, oranges, limes, grapefruit, guava, mango, cherries, kiwi, blueberries, raspberries, all varieties of grapes, parsley and thyme. Fruits and vegetables rich in magnesium include apples, bananas, tomatoes, avocados, pineapples, melons, peaches, pears, spinach, cauliflower, broccoli, asparagus, green lettuce, Brussels sprouts and green beans. Non-limiting examples of food rich in zinc include pumpkins, yeast, peanuts, whole grains, beans, and brown rice.

[0087] Other possible treatment of preventive measures include the administration of agents which increase OPN expression or secretion (e.g., angiotensin, tumour necrosis factor α (TNF α), interleukin-1 β (IL-1 β)), angiotensin II, transforming growth factor β (TGF β) and parathyroid hormone (PTH)), low intensity pulsed ultrasounds (LIPUS), and treatment and preventive measure which decrease CD44 expression or binding to OPN (e.g., an antibody or siRNA specific for CD44/sCD44). Also, FG1 subjects should avoid diets rich in selenium since selenium is a powerful inhibitor of OPN or any other nutraceutical that decreases OPN level.

[0088] As indicated above, as opposed to the FG1 group, FG2 and FG3 subjects are particularly sensitive to OPN. High OPN levels in these subjects increase the risk of scoliosis development and progression. Generally, for FG2 and FG3 subjects, preventive and treatment measures should aim at maintaining their level of OPN as low as possible, especially since these subjects are sensitive to OPN (especially FG2 subjects, which are the most sensitive to OPN i.e hypersensitive). Accordingly, any treatment or preventive measure which will help decreasing or maintaining the level or activity of OPN as low as possible is desirable for FG2 and FG3 subjects. Non-limiting examples of such treatment or preventive measure include,, accupoint heat sensitive moxibustion, heat therapies with pad, thermal baths, electroacupuncture, which are known to decrease OPN in serum of subjects.

[0089] For FG2 and FG3 subjects, possible treatment and preventive measures also includes administration of an OPN antagonist to reduce OPN levels (administration of OPN antagonists (e.g., melatonin, selenium supplements or selenium from the diet (e.g. Brazil nuts), the use of nutraceutical like PROTANDIM) and/or brace treatment as it is likely to be beneficial to these subjects, especially to FG3 subjects. In FG2 and FG3 subjects having low levels of OPN, brace treatment could be postponed

or not prescribed at all depending on the skeletal maturity, age and sex of the subject but if prescribed, it will be for preferably be at least 12-18 months, more preferably 24-36 months and even more preferably for 36 months or more, or for a sufficient time to induce a significant reduction in OPN levels. In a specific embodiment brace treatment will last at least 12, 18, 24, 30 or 36 months.

[0090] Since HA exacerbates the effect of OPN, FG2 and FG3 subjects should avoid taking HA supplements and preferably avoid taking food with high HA content or which stimulates/support HA production (e.g., comply to a HA-poor or HA-low diet). Similarly, any compound (synthetic or natural) or activity which are known to increase the level of OPN or HA should preferably be avoided (e.g., angiotensin, tumour necrosis factor α (TNF α), interleukin-1 β (IL-1 β), angiotensin II, transforming growth factor β (TGF β) and parathyroid hormone (PTH, regular application of compressive pressure (e.g., pulsative compressive pressure), LIPUS, etc.).

[0091] As disclosed herein, CD44 inhibition further decreases the Gi-mediated cellular response in FG2 and FG3 subjects. Accordingly, FG2 and FG3 subjects could also be treated with soluble CD44 or any compound which will increase its level. Furthermore, as the effect of OPN on the Gi-mediated response is dependent on the binding of OPN to integrins (e.g., $\alpha 5 \beta 1$), molecules that specifically block the binding of OPN to integrins are also considered useful. For example, one known molecule that specifically blocks the binding of OPN to integrin (e.g., $\alpha 5 \beta 1$) is a RGD peptide or derivative thereof. Other useful molecules include a peptide fragment of OPN comprising a RGD motif (e.g., GRGDSVYGLRS (SEQ ID NO: 13); an siRNA specific for an integrin (e.g., $\alpha 5$, $\beta 1$, $\beta 3$ or $\beta 5$) or an antibody against an integrin (e.g., $\alpha 5$, $\beta 1$, $\beta 3$ and/or $\beta 5$ and/or volociximabTM; etaratuzumabTM, etaracizzumabTM, VitaxinTM, MEDI-522 or CNT095).

[0092] Preferably, the level of OPN in the subject should be monitored periodically (e.g., every 6 months, every 5 months, every 4 months, preferably every 2 or 3 months, even more preferably every month) prior to and during any form of treatment or preventive measures and the frequency of OPN level monitoring increased when the level approaches retroinhibition concentration (e.g., 580-1000 ng/ml of OPN) in order to adapt treatment. For Example, for FG1 subjects having low levels of OPN, brace treatment could be performed, stopped when the level of OPN approaches retroinhibition concentration and restarted later (e.g., 6-18 months later) so as to induce another surge in OPN level. This cycle could be repeated as necessary.

[0093] The present invention also provides a method of predicting the risk of developing IS in a subject comprising: a) classifying the subject into functional group FG1, FG2 or FG3; and b) determining

the level of circulating OPN in a blood sample from the subject, wherein when the subject is classified into the FG1 functional group and the level of circulating OPN in the blood sample of the subject is low, the subject has an increased risk of curve progression (as compared to FG1 subjects having high circulating level of OPN); and wherein when the subject is classified into the FG2 or FG3 functional group and the level of circulating OPN in the blood sample of the subject is high, the subject has an increased risk of curve progression (as compared to FG2 or FG3 subjects having low circulating level of OPN).

[0094] The present invention also provides kits for predicting the risk of developing scoliosis, for predicting brace treatment outcome and for selecting the best treatment or preventive measures. Such kits may comprise one or more reagents for classifying subjects into functional group FG1, FG2, or FG3 such as (a) one or more ligands (e.g., agonists) for stimulating GiPCRs; (b) ligands (e.g., antibodies) for detecting $G_{i\alpha}$ proteins ($G_{i\alpha 1}$, $G_{i\alpha 2}$ and $G_{i\alpha 3}$) and their phosphorylation pattern (e.g., antibodies for detecting serine phosphorylation); and/or (c) reagents for determining cellular proliferation; and optionally (d) (i) one or more ligands for stimulating GsPCRs (e.g., agonists) and (ii) instructions for using the kit. The kit may further comprise reagents for determining the level of circulating OPN in a blood sample such as primary antibodies (labeled or not) against OPN and optionally secondary antibodies to detect the binding of primary antibodies.

Definitions

[0095] For clarity, definitions of the following terms in the context of the present invention are provided.

[0096] Methods of classifying subjects into a functional group (FG1, FG2 or FG3) according to the degree of their imbalance in Gi-mediated cellular signaling are known in the art and have been described previously (see for example, Moreau et al. (2004), Akoume et al., (2010), Akoume et al., (2013), Azeddine et al., 2007; Letellier et al., 2008; WO2003/073102, WO2010/040234, copending PCT Appl. No. PCT/CA2014/050562, and copending US application No. 61/875,162 to Moreau, which are incorporated herein by reference in their entirety). Hence, in accordance with the present invention, any method or combination of methods of classifying a subject into the FG1, FG2 or FG3 group can be used. Non-limiting examples of classifying subjects following Gi-stimulation include i) detection of changes in cAMP concentration (Moreau et al., 2004), ii) change in cellular impedance (e.g., by cellular dielectric spectroscopy (CDS), Akoume et al., 2010 and Akoume et al., 2013b), detection of Gi phosphorylation pattern (Akoume et al. 2013), and cellular proliferation rate (WO03073102 and co-

pending US application No. 61/875,162). Classification may also be effected by determining the degree of imbalance between Gi and Gs as described in Akoume et al., 2013; Akoume et al., 2013b; and US application No. 61/875,162).

[0097] As used herein, the terms “brace treatment outcome” refers to a genetic or metabolic predisposition of a subject to benefit or not from brace treatment. Non-limiting examples of brace treatment outcome includes: i) a final Cobb angle $\leq$ to 45 °; ii) a final Cobb angle $\geq$ to 45 (severe scoliosis)°; iii) curve progression; iv) absence of curve progression; and v) need for surgery or any other benefit that may be measured following brace treatment. A curve progression is defined as a progression of Cobb’s angle $\geq$ to 6°.

[0098] A “successful brace treatment” or “brace treatment success” is a brace treatment following which the Cobb’s angle is $\leq$ to 45 ° or no surgery is required.

[0099] As used herein, the term “benefit” in for example, “benefit from brace treatment” means that brace treatment has a positive effect on the prevention and/or treatment of IS. For example, a “benefit” of brace treatment can be one or more of: i) a reduction in the speed of curve progression; ii) a complete prevention of curve progression (i.e., a curve progression $\leq$ 6°); iii) a reduction of Cobb’s angle in a preexisting spinal deformity; iv) improvement of column mobility; v) preservation/maintenance of column mobility; vi) improvement of equilibrium and balance in a specific plan; vii) maintenance/preservation of equilibrium and balance in a specific plan; viii) improvement of functionality in a specific plan; ix) preservation/maintenance of functionality in a specific plan; ix) cosmetic improvement; x) avoidance of corrective surgery; and xi) combination of at least two of any of i) to x) .

[00100] As used herein, the term “likely” in for example, “likely to have a successful brace treatment” refers to an increased chance of having a Cobb’s angle $\leq$ to 45 ° or of not requiring surgery as compared to IS subjects in general, following brace treatment. In an embodiment, the increased chance of having successful brace treatment refers to a 50% chance or more (e.g., 60%, 65%, 70%, 75%, 80%, 85%... etc.) of having a Cobb’s angle $\leq$ to 45 ° or of not requiring surgery following brace treatment. Similarly, the term “unlikely” (or less likely) in for example “unlikely to have a successful brace treatment” refers to a decreased chance of having a Cobb’s angle $\leq$ to 45 ° or of not requiring surgery as compared to IS subjects in general, following brace treatment. In an embodiment, the decreased chance of having successful brace treatment refers to less than 50% chance (e.g., 49%, 45% 40%,

35%, 30%, 25%, 20%... etc.) of having a Cobb's angle $\leq$ to 45° or of not requiring surgery following brace treatment.

[00101] As used herein the term "subject" is meant to refer to any mammal including human, mouse, rat, dog, chicken, cat, pig, monkey, horse, etc. In a particular embodiment, it refers to a human. In a specific embodiment, the subject is a pediatric subject. In an embodiment, the subject is skeletally immature.

[00102] As used herein, the terms "subject in need thereof" refer to a subject already diagnosed with IS or at risk of developing IS (i.e., a likely candidate for developing scoliosis). In an embodiment, the subject in need thereof is a subject already diagnosed with idiopathic scoliosis. In an embodiment, the subject in need thereof is an asymptomatic subject having at least one family member having been diagnosed with idiopathic scoliosis. In an embodiment, the subject in need thereof is a pediatric subject.

[00103] In an embodiment, the above-mentioned subject is a likely candidate for developing a scoliosis, such as idiopathic scoliosis (e.g., Infantile Idiopathic Scoliosis, Juvenile Idiopathic Scoliosis or Adolescent Idiopathic Scoliosis (AIS)). As used herein the terms "likely candidate for developing scoliosis" include subjects (e.g., children) of which at least one parent has a scoliosis (e.g., adolescent idiopathic scoliosis). Among other factors, age (adolescence), gender and other family antecedent are factors that are known to contribute to the risk of developing a scoliosis and are used to a certain degree to assess the risk of developing a scoliosis. In certain subjects, scoliosis develops rapidly over a short period of time to the point of requiring a corrective surgery (often when the deformity reaches a Cobb's angle $\geq 50^\circ$). Current courses of action available from the moment a scoliosis such as AIS is diagnosed (when scoliosis is apparent) include observation (when Cobb's angle is around $10-25^\circ$), orthopedic devices (when Cobb's angle is around $25-30^\circ$), and surgery (over 45°). A more reliable determination of the risk of progression could enable to 1) select an appropriate diet to remove certain food products identified as contributors to scoliosis; 2) select the best therapeutic agent; and/or 3) select the least invasive available treatment such as postural exercises, orthopedic device, or less invasive surgeries or surgeries without fusions (a surgery that does not fuse vertebra and preserves column mobility). The present invention encompasses selecting the most efficient and least invasive known preventive actions or treatments in view of the determined risk of developing scoliosis.

[00104] As used herein, the terms "severe scoliosis", "severe IS" or "severe progression" is an increase of the Cobb's angle to 45° or more, potentially at a younger age.

[00105] As used herein the term “treating” or “treatment” in reference to idiopathic scoliosis (e.g., Infantile Idiopathic scoliosis (0-2 years old at the time of onset), Juvenile Idiopathic scoliosis (from 4 to 9 years old at the time of onset) and Adolescent Idiopathic scoliosis (from 10 to 17 years old at the time of onset) is meant to refer to e.g., at least one of a reduction of Cobb's angle in a preexisting spinal deformity, improvement of column mobility, preservation/maintenance of column mobility, improvement of equilibrium and balance in a specific plan; maintenance/preservation of equilibrium and balance in a specific plan; improvement of functionality in a specific plan, preservation/maintenance of functionality in a specific plan, cosmetic improvement, and combination of at least two of any of the above.

[00106] As used herein the term “preventing” or “prevention” in reference to scoliosis is meant to refer to a at least one of a reduction in the progression of a Cobb's angle in a patient having a scoliosis, a reduction in the speed of curve progression; or, in an asymptomatic patient, a complete prevention of apparition of a spinal deformity, including changes affecting the rib cage and pelvis in 3D, or a combination of any of the above.

[00107] As used herein the terms “at risk of developing a scoliosis” or “at risk of developing IS” refer to a genetic or metabolic predisposition of a subject to develop a scoliosis (i.e. spinal deformity) and/or a more severe scoliosis at a future time (i.e., curve progression of the spine). For instance, an increase of the Cobb's angle of a subject (e.g., from 40° to 50° or from 18° to 25°) is a “development” of a scoliosis. The terminology “a subject at risk of developing a scoliosis” includes asymptomatic subjects which are more likely than the general population to suffer in a future time of a scoliosis such as subjects (e.g., children) having at least one parent, sibling or family member suffering from a scoliosis. Among others, age (adolescence), gender and other family antecedent are factors that are known to contribute to the risk of developing a scoliosis and are used to evaluate the risk of developing a scoliosis. Also included in the terminology “a subject at risk of developing a scoliosis” are subjects already diagnosed with IS but which are at risk to develop a more severe scoliosis (i.e. curve progression).

[00108] As used herein, a “low” level of OPN (e.g., Gene ID 6696, NP_001035147.1 (SEQ ID NO: 1) and NM_001040058 (SEQ ID NO: 2) SPP1- Gene ID: 6696, OPNa: NP_001035147.1, OPNb: NP_000573.1, OPNc: NP_001035149.1, OPN Isoform 4: NP_001238758.1, OPN Isoform 5: NP_001238759.1, NM_001251829.1, GI_352962173); is a level of OPN that is lower than the average level of OPN in IS (e.g., AIS) subjects. In an embodiment, the IS subjects are matched for age and/or

sex. In another embodiment, the IS subjects are matched to a specific functional group (FG1, FG2 or FG3). In a specific embodiment, a low level of OPN is a level of OPN < than about 600 ng/ml, 580 ng/ml; 575 ng/ml, 560 ng/ml, 550 ng/ml, 520 ng/ml, 500 ng/ml, 450 ng ml, 400 ng/ml or 300 ng/ml. In specific embodiment, a low level of OPN is a level of OPN < 600 ng/ml in a blood sample from the subject. In another specific embodiment, a low level of OPN is a level of OPN $\leq$ 500 ng/ml in a blood sample from the subject. In another specific embodiment, a low level of OPN is a level of OPN $\leq$ 250 ng/ml in a blood sample from the subject. In another specific embodiment, a low level of OPN is a level of OPN that is about that of healthy subjects. In a specific embodiment, for FG2 subjects (which are hypersensitive to OPN), in the context of the treatment method of the present invention, the level of OPN is maintained as low as possible, preferably below 400 ng/ml, more preferably below 300 ng/ml and even more preferably below 200 ng/ml.

[00109] As used herein, a "high" level of OPN (e.g., Gene ID 6696, NP_001035147.1 (SEQ ID NO: 1) and NM_001040058 (SEQ ID NO:2) is a level of OPN that is higher than the average level of OPN in IS (e.g., AIS) subjects. In an embodiment, the IS subjects are matched for age and/or sex. In another embodiment, the IS subjects are matched to a specific functional group (FG1, FG2 or FG3). In a specific embodiment, a high level of OPN is a level of OPN $\geq$ than about 1200 ng/ml, 1000 ng/ml, 900, ng/ml, 850 ng/ml, 800 ng/ml, 750 ng/ml, 700 ng/ml, 550 ng/ml, 580 ng/ml, 600 ng/ml; 610 ng/ml, 620 ng/ml, 630 ng/ml, 650 ng/ml, 675 ng/ml, 700ng/ml or 750ng/ml. In a specific embodiment, a high level of OPN is a level of OPN between about 650-1000 ng/ml in a blood sample from the subject. In another specific embodiment, a high level of OPN is a level of OPN $\geq$ 600 ng/ml in a blood sample from the subject. In another embodiment, a high level of OPN is a level of OPN that is close to but below the retroinhibition concentration (e.g., 80%, 85%, 90%, 95% of the retroinhibition concentration). In another specific embodiment, for FG1 subjects, in the context of the treatment method of the present invention, the level of OPN is maintained as high as possible, preferably above 500 ng/ml, above 800 ng/ml or above 900ng/ml and even more preferably above 1000 ng/ml or above 1200 ng/ml.

[00110] As used herein, the term "retroinhibition concentration" refers to the *in vivo* concentration at which OPN level reaches its maximum and the retroinhibition mechanism is induced so as to decrease the level of circulating OPN in the blood endogenously.

[00111] As used herein, the term "retroactivation concentration" refers to the *in vivo* concentration at which OPN level reaches its minimum and the retroactivation mechanism is induced so as to increase the level of circulating OPN in the blood endogenously. In a specific embodiment, it refers the

concentrations of OPN at which brace treatment first induces an increase in OPN level. In an embodiment, the retroactivation concentration is 600 ng/ml or less, preferably 500 ng/ml or less and even more preferably, 400 ng/ml or less.

[00112] As used herein the terms "follow-up schedule" is meant to refer to future medical visits a subject diagnosed with a scoliosis or at risk of developing a scoliosis is prescribed once the diagnosis or risk evaluation is made. For example, when a subject is identified as belonging to the FG1 functional group and as having a low level of OPN (and the subject is prescribed OPN, an OPN agonist or treatment and preventive measures which increase OPN levels), the number of medical visits are increased to make sure that OPN levels are stable, preferably increase and remain as high as possible. In addition, in the rare case where an FG1 subject is prescribed a brace treatment, the number of medical visits is increased to make sure that brace treatment lasts for an optimal time and the level of OPN does not decrease. For example, OPN levels could be monitored every 2 months, preferably every month and the treatment adjusted in view of the detected OPN level. For example, when OPN level reached or approached retroinhibition concentration treatment would be stopped completely or temporarily until OPN level decrease sufficiently and the treatment could be started again. In addition, or alternatively, curve progression could be monitored and the treatment maintained until curve progression is detected. Another limiting example include when a subject being at risk of developing a severe scoliosis or at risk of rapid curve progression (e.g., a subject classified as belonging to the FG2 functional group and having a high level or circulating OPN), the number of medical visits (e.g., to the orthopedist) is increased, the frequency of OPN monitoring is increased and/or the number of x-rays in a given period (e.g., 1, 2, 3, 6 or 12 months) is increased. On the other hand, when a subject is identified as having a lower risk of curve progression or rapid curve progression (e.g., subject being classified as belonging to the FG1 functional group and having high levels of OPN) the number of medical visits, OPN level monitoring or x-rays may be decreased to less than the average (e.g., less than 22 x-rays over a 3 year period or less than 1 visit every month, every 3 months, 6 months or 12 months). The follow-up schedule and OPN monitoring frequency is adapted in view of several factor including sex, age, Cobb's angle, skeletal maturity (Risser of 5), menarche, functional classification (FG1, FG2 or FG3) and OPN level.

[00113] As used herein, the term "brace treatment" refers to the use of a brace for reducing (i.e. slowing or stopping) curve progression of the scoliosis or for improving scoliosis (i.e., reversing completely or partially the scoliosis, e.g., a reduction of a Cobb's angle from 30 to 24°). There are a

number of bracing options known in the art. Non-limiting examples of braces used in the treatment of scoliosis include the Thrombo-Lumbar-Sacral Orthosis (TLSO) brace, the Milwaukee brace, the Charleston brace and the SpineCor™ brace. Other examples include, the Dynamic scoliosis orthosis brace (DSO) (US Application No. 12/145,959); scoliosis braces with angle adjustment (US 2009/0137934) and braces with adjustable inflatable air bags (US2009/0275871). The physician will recommend a particular back brace and bracing schedule based on factors such as the location of the curve, degree of curvature (Cobb's angle), age, growth status of the IS subject (e.g., pre or post menarche, and skeletal maturity (Risser of 5), endophenotype (IS functional group) and lifestyle (e.g., for subjects involved in sports, a more flexible brace (e.g., SpineCor™ or Charleston may be favored). Moreover, a combination of braces may also be prescribed (e.g., a TLSO brace for day time and a Charleston brace for night time).

[00114] The most common form of TLSO brace is called the "Boston brace", and it may be referred to as an "underarm" brace. This brace is fitted to the child's body and custom molded from plastic. It works by applying three-point pressure to the curvature to prevent its progression. The TLSO brace is usually worn 23 hours/day, and it can be taken off to swim, play sports or participate in gym class during the day. This type of brace is usually prescribed for curves in the lumbar or thoraco-lumbar part of the spine.

[00115] The Cervico-Thoraco-Lumbo-Sacral-Orthosis brace (Milwaukee brace) is similar to the TLSO described above, but also includes a neck ring held in place by vertical bars attached to the body of the brace. It is usually worn 23 hours a day, and can be taken off to swim, play sports or participate in gym class during the day. This type of brace is often prescribed for curves in the Thoracic spine.

[00116] The Charleston brace, also called nighttime brace is a back brace which is molded to the patient while they are bent to the side, and thus applies more pressure and bends the child against the curve. This pressure improves the corrective action of the brace. This type of brace is worn only at night while the child is asleep. Curves must be in the 20 to 40 degree range and the apex of the curve needs to be below the level of the shoulder blade for the Charleston brace to be effective.

[00117] In accordance with the present invention, the skilled practitioner (e.g., the treating physician) can select the most appropriate treatment regimen based on the subject's classification. The particular choice of treatment or combination of treatment will be adapted based on the subject's classification and optionally based on his/her level of circulating OPN. For example, brace treatment may be delayed, shortened/lengthened, the choice of a particular brace or braces adapted (in view of

age, sex, and Cobb's angle) and the time at which surgery is performed (if needed) modified in view of the subject's classification and optionally, circulating OPN level.

[00118] In the context of treating FG1 subjects with a brace, a "short" brace treatment or "short term" brace treatment include brace treatment for 18 months or less, preferably 12 months or less and more preferably, 6 months or less (e.g., 1, 2, 3, 4, 5 or 6 months). Preferably, if brace treatment is prescribed for FG1 subjects, the brace treatment may be continued until the OPN concentration reaches its maximal concentration or close to its maximal concentration (retroinhibition concentration). In an embodiment, brace treatment will be continued until OPN concentration starts declining in the subject. In a specific embodiment, brace treatment is continued until OPN concentration reaches 700, 800, 1000, 1100 or 1200 or more ng/ml.

[00119] In the context of treating FG2 and FG3 subjects with a brace, a "long" brace treatment or "long-term" brace treatment includes brace treatment for at least 18 months (e.g., 18, 19, 20, 21, 22, 23 months), preferably at least 24 months (e.g., 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35 months) and more preferably, at least 36 months. Preferably, for FG2 and FG3 subjects brace treatment will be continued until OPN concentration is significantly reduced or until skeletal maturity is reached. In a specific embodiment, brace treatment is maintained until the OPN concentration reaches its minimum or until the OPN concentration begins increasing. In a specific embodiment, brace treatment is maintained up to two years after menarche in a female subject. In a particular embodiment, brace treatment is maintained until the concentration of OPN reaches less than 600 ng/ml, preferably less than 500 ng/ml or until the OPN concentration reaches its minimum or starts increasing. In a particular embodiment for FG3 subjects, brace treatment is maintained until the concentration of OPN reaches less than 600 ng/ml, preferably less than 500 ng/ml. In another particular embodiment, for FG2 subjects brace treatment is maintained until the concentration of OPN reaches less than 400 ng/ml, preferably less than 300ng/ml more preferably less than 200 ng/ml (due to their hypersensitivity toward OPN).

[00120] The terms "activator" or "agonist" are well known in the art and are used herein interchangeably. Similarly, the terms "suppressor", "inhibitor" and "antagonist" are well known in the art and are used herein interchangeably

[00121] As used herein, the expression "OPN agonist" or "OPN activator" is used to refer to any compound capable to increase, at least partially, the level and/or desired biological activity of OPN (e.g., Gene ID 6696, NP_001035147.1 (SEQ ID NO: 1) and NM_001040058 (SEQ ID NO:2) SPP1- Gene ID: 6696, OPNa: NP_001035147.1, OPNb: NP_000573.1, OPNc: NP_001035149.1, OPN Isoform 4:

NP_001238758.1, OPN Isoform 5: NP_001238759.1, NM_001251829.1, GI_352962173). Without being so limited it includes OPN functional fragment or derivative thereof and activators of OPN expression such as (but not limited to) transcriptional and translational activators of the OPN gene (e.g., tumour necrosis factor α (TNF α), interleukin-1 β (IL-1 β), angiotensin II (Ang II), transforming growth factor β (TGF β) and parathyroid hormone (PTH)). Activator of OPN activity includes compounds that are able to bind to OPN receptors in order to increase the desired biological activity of OPN, peptidomimetics, OPN fragments and the like. In a specific embodiment, the OPN biological activity is an increase in Gi-mediated cellular response in FG1 subjects and the OPN activator or agonist is HA.

[00122] As used herein, the term “functional fragment” of OPN refers to a molecule (e.g., polypeptide) which retains substantially the same desired activity as the original molecule but which differs by any modifications, and/or amino acid/nucleotide substitutions, deletions or additions (e.g., fusion with another polypeptide). Modifications can occur anywhere including the polypeptide/polynucleotide backbone (e.g., the amino acid sequence, the amino acid side chains and the amino or carboxy termini). Such substitutions, deletions or additions may involve one or more amino acids or in the case of polynucleotide, one or more nucleotide. The substitutions are preferably conservative, i.e., an amino acid is replaced by another amino acid having similar physico-chemical properties (size, hydrophobicity, charge/polarity, etc.) as well known by those of ordinary skill in the art. Functional fragments of OPN (SEQ ID NO:1) include a fragment or a portion of OPN polypeptide or a fragment or a portion of a homologue or allelic variant of OPN which retains activity, i.e., binds to integrins (e.g., $\alpha 5 \beta 1$) and/or CD44. In an embodiment, the OPN functional fragment is at least 80, 85, 88, 90, 95, 98 or 99% identical to the polypeptide sequence of (SEQ ID NO:1). In an embodiment, the OPN functional fragment is a functional variant which includes variations in amino acids which are not conserved between rat, mouse and human OPN. Preferably, the OPN functional fragment is human. A “functional derivative” refers to a molecule derived from the OPN polypeptide or polynucleotide and which is substantially similar in structure and biological activity to the OPN protein or nucleic acid of the present invention. An OPN polypeptide derivative may for example include modifications to increase its bioavailability, its stability, to simplify its purification or to preferentially target the OPN derivative to a particular tissue or cell.

[00123] As used herein, the expression “OPN antagonist” or “OPN inhibitor” is used to refer to any compound capable to block completely or partially (i.e., negatively affect) the expression (at the transcriptional (mRNA) and/or translational (protein)) level or targeted biological activity of OPN (e.g., binding to one or more of its integrin receptors) in cells. In an embodiment, the biological activity of OPN in cells is a reduction in GiPCR signaling. OPN inhibitors include intracellular as well as extracellular

suppressors. Without being so limited, such suppressors include RNA interference agents (siRNA, shRNA, miRNA), antisense molecules, ribozymes, proteins (e.g., dominant negative, inactive variants), peptides, small molecules, antibodies, antibody fragments, etc. In an embodiment, the OPN antagonist is a neutralizing antibody against human OPN. In an embodiment, the OPN antagonist is melatonin. In an embodiment, the OPN antagonist is selenium. In an embodiment, the OPN antagonist is PROTANDIM™. In an embodiment, the OPN antagonist is soluble CD44 (sCD44) or a stimulator or enhancer of sCD44/CD44 expression.

[00124] As used herein, the expression “integrin antagonist” or “integrin inhibitor” is used to refer to any compound capable to block completely or partially (i.e., negatively affect) the expression (at the transcriptional (mRNA) and/or translational (protein)) level or targeted biological activity of integrins (e.g., binding to OPN) in cells. In an embodiment, the biological activity of integrins in cells is a reduction in GiPCR signaling. Integrin inhibitors include intracellular as well as extracellular suppressors. Without being so limited, such suppressors include RNA interference agents (siRNA, shRNA, miRNA), antisense molecules, ribozymes, proteins (e.g., dominant negative, inactive variants), peptides, small molecules, antibodies, antibody fragments, etc. In an embodiment, the integrin antagonist is a neutralizing antibody against human integrin (volociximab™; etaratuzumab™, etaracizzumab™, Vitaxin™, MEDI-522, CNT095, cilengitide™).

[00125] The terms “inhibitor of OPN expression” or “inhibitor of integrin expression” (e.g., α_5 , β_1 , β_3 and/or β_5) expression” include any compound able to negatively affect OPN's or integrin's (e.g., α_5 's, β_1 's, β_3 's and/or β_5 's) expression (i.e., at the transcriptional and/or translational level), i.e. the level of OPN/ integrin mRNA and/or protein or the stability of the protein. Without being so limited, such inhibitors include agents which negatively affect the expression of OPN (e.g., vitamin D, melatonin, selenium, PROTANDIM™) or integrin, RNA interference agents (siRNA, shRNA, miRNA), antisense molecules, and ribozymes. Such RNA interference agents are design to specifically hybridize with their target nucleic acid under suitable conditions and are thus substantially complementary their target nucleic acid.

[00126] The terms “inhibitor of OPN activity” or “inhibitor of integrin activity” (e.g., (e.g., α_5 , β_1 , β_3 and/or β_5) refers to any molecules that is able to reduce or block the effect of OPN or integrins (e.g., $\alpha_5\beta_1$) on Gi-mediated signaling. These molecules increase GiPCR signaling in cells (i.e., in FG2 and FG3 subjects) by blocking/reducing totally or partially the inhibitory effect induced by OPN and/or integrins activity. Non-limiting examples of inhibitors of OPN's activity include proteins (e.g., dominant negative, inactive variants), peptides, small molecules, anti-OPN antibodies (neutralizing antibodies), antibody fragments, inactive fragments of α_5 and/or β_1 integrins etc. Non-limiting examples of inhibitors

of integrin (e.g., $\alpha_5\beta_1$) activity include proteins (e.g., dominant negative, inactive variants), peptides (RGD peptides or RGD peptide-derivatives), small molecules, anti α_5 and/or β_1 antibodies (e.g., neutralizing antibodies such as Volociximab™ M200, etaratuzumab™, etaracizzumab™, Vitaxin™, MEDI-522, CNT095, cilengitide™), antibody fragments, etc. In an embodiment, the RGD peptide is a peptide fragment of OPN comprising a RGD motif comprising the amino acid sequence GRGDSVYGLRS corresponding to amino acid 158 to 169 of OPN (SEQ ID NO:1). In an embodiment, the OPN fragment comprising the RGD motif comprises amino acids 158 to 162, 158 to 165, 158 to 167, 158 to 170, 158 to 175, 158 to 180, 158 to 185, 158 to 190, 158 to 195, or 158 to 200 of OPN (e.g., SEQ ID NO: 1). In an embodiment, peptide fragment of OPN comprising a RGD motif comprises amino acids 158 to 161, 156 to 161, 154 to 161, 152 to 162, 150 to 162, 148 to 162, 146 to 162, 144 to 162, 140 to 162, 159 to 163, 159 to 164, 159 to 162, 159 to 166, 159 to 167, or 159 to 169 of OPN (e.g., SEQ ID NO: 1).

[00127] In an embodiment, the “inhibitor of OPN's activity” is a neutralizing antibody directed against (or specifically binding to) a human OPN polypeptide which inhibits its binding to integrins such as $\alpha_5\beta_1$ (i.e, binding to α_5 and/or β_1 integrin) In an embodiment, the “inhibitor of integrin activity” is a neutralizing antibody directed against (or specifically binding to) a human integrin (α_5 , β_1 , β_3 and/o β_5) polypeptide which inhibits the binding of OPN to integrins (i.e, binding to α_5 β_1 , β_3 and/o β_5 integrin). In an embodiment, the antibody binds to the RGD domain of OPN. In an embodiment, the antibody is directed against amino acids 159 to 162, 158 to 162, 158 to 165, 158 to 167, 158 to 170, 158 to 175, 158 to 180, 158 to 185, 158 to 190, 158 to 195, or 158 to 200 of OPN (e.g., SEQ ID NO: 1). In an embodiment, the antibody is directed against amino acids 158 to 161, 156 to 161, 154 to 161, 152 to 162, 150 to 162, 148 to 162, 146 to 162, 144 to 162, 140 to 162, 159 to 163, 159 to 164, 159 to 162, 159 to 166, 159 to 167, or 159 to 169 of OPN (e.g., SEQ ID NO: 1).

[00128] Similarly, the terms “inhibitor of integrin's activity”, “inhibitor of $\alpha_5\beta_1$'s activity”, “inhibitor of α_5 's activity” or “inhibitor of β_1 's activity”, “inhibitor of β_3 's activity”, “inhibitor of β_5 's activity” and the like include any compound able to negatively affect the expression and/or activity of α_5 (e.g., Gene ID 3678, NP_002196.2 (SEQ ID NO: 5) and NM_002205.2 (SEQ ID NO: 6)), β_1 (Gene ID 3688, NP_002202.2 (SEQ ID NO: 7) and NM_002211.3 (SEQ ID NO: 8)), β_3 (Gene ID 3690, NP_000203.2 (SEQ ID NO: 9) and NM_000212 (SEQ ID NO: 10) and/or β_5 (Gene ID 3693, NP_002204.2 (SEQ ID NO: 11) and NM_002213.3 (SEQ ID NO:12)) in cells. In a particular embodiment, the “activity” of α_5 and/or β_1 in cells is the transduction of the signal leading to the OPN-dependent inhibition of GiPCR signaling. In a particular embodiment, the inhibitor is Volociximab™ M200, etaratuzumab™, etaracizzumab™, Vitaxin™, MEDI-522, CNT095 or cilengitide™.

[00129] The term “inhibitor” of sCD44/CD44 expression (e.g., Gene ID 960, NP_000601.3, (SEQ ID NO: 3), NM_000610 (SEQ ID NO: 4)) refers to an agent able to decrease the level of expression of CD44 and an agent able to decrease CD44 secretion. In an embodiment, the inhibitor of sCD44/CD44 is an agent able to decrease CD44 binding with OPN. Without being so limited, the agent can be a protein (e.g., an antibody specific to CD44), a peptide, a small molecule or a nucleotide. Inhibitors of sCD44 or CD44 generally increase OPN's bioavailability for other receptor of OPN (e.g., integrins) and may be particularly useful for treating and preventing scoliosis development in FG1 subjects.

[00130] The term “stimulator” or “enhancer” of sCD44/CD44 expression (e.g., Gene ID 960, NP_000601.3, (SEQ ID NO: 3), NM_000610 (SEQ ID NO: 4)) refers to an agent able to increase the level or expression of CD44 and an agent able to increase CD44 secretion. In an embodiment, the stimulator of sCD44/CD44 is an agent able to increase CD44 affinity toward OPN. Without being so limited, the agent can be a protein, a peptide, a small molecule or a nucleotide. “Stimulators” or “enhancers” of sCD44/CD44 expression generally decrease OPN's bioavailability for other receptor of OPN (e.g., integrins) and may be particularly useful for treating and preventing scoliosis development in FG2 and FG3 subjects.

Antibodies

[00131] In general, techniques for preparing antibodies (including monoclonal antibodies and hybridomas) and for detecting antigens using antibodies are well known in the art (Campbell, 2000, In “Monoclonal Antibody Technology: The production and characterization of Rodent and Human Hybridomas”, Elsevier Science Publisher, Amsterdam, The Netherlands) and Recombinant Monoclonal Antibodies (Mariel Donzeau and Achim Knappik; Methods in Molecular Biology; Volume 378, 2007, pp 15-31).

[00132] As used herein, the term “anti-OPN antibody”, refers to an antibody that specifically binds to (interacts with) OPN and displays no substantial binding to other naturally occurring proteins other than the ones sharing the same antigenic determinants as OPN. Similarly, the expression “anti-CD44 antibody”, “anti- β_1 antibody” and the like (anti- α_5 , anti- β_3 , anti- β_5 ...) refers to an antibody that specifically binds to (interacts with) CD44 or β_1 and displays no substantial binding to other naturally occurring proteins other than the ones sharing the same antigenic determinants as CD44/ β_1 . The term “antibody” or “immunoglobulin” is used in the broadest sense, and covers monoclonal antibodies (including full length monoclonal antibodies), polyclonal antibodies, multispecific antibodies, and antibody fragments so long as they exhibit the desired biological activity. Antibody fragments comprise a

portion of a full length antibody, generally an antigen binding or variable region thereof. Examples of antibody fragments include Fab, Fab', F(ab')₂, and Fv fragments, diabodies, linear antibodies, single-chain antibody molecules, single domain antibodies (e.g., from camelids), shark NAR single domain antibodies, and multispecific antibodies formed from antibody fragments. Antibody fragments can also refer to binding moieties comprising CDRs or antigen binding domains including, but not limited to, VH regions (VH, VH-VH), anticalins, PepBodies™, antibody-T-cell epitope fusions (Troybodies) or Peptibodies. Additionally, any secondary antibodies, either monoclonal or polyclonal, directed to the first antibodies would also be included within the scope of this invention. In an embodiment, the antibody is a monoclonal antibody. In another embodiment, the antibody is a humanized or CDR-grafted antibody.

Table 1 commercially available human OPN Elisa kits.

Company	Kit name	Catalogue number	Sensitivity
IBL Hambourg	Human Osteopontin ELISA	JP 171 58	3,33ng/ml
IBL America	Human Osteopontin N-Half Assay Kit - IBL	27258	3,90 pmol/L
IBL-America	Human Osteopontin Assay Kit - IBL	27158	3,33ng/ml
Assay designs	Osteopontin (human) EIA Kit	900-142	0,11ng/ml
American Research Products, Inc.	Osteopontin, human kit	17158	?
R&D Systems	Human Osteopontin (OPN) ELISA Kit	DOST00	0.024 ng/mL
Promokine	Human Osteopontin ELISA	PK-EL-KA4231	3,6ng/ml
.Uscnlife	Human Osteopontin,OPN ELISA Kit	E0899h	?

[00133] Table 2: Non-limiting examples of commercially available antibodies for OPN (Human, Unconjugated)

Company Name	Catalogue Number	Host
EMD Millipore	AB10910	rabbit
Boster Immunoleader	PA1431	
LifeSpan BioSciences	LS-C63082-100	mouse
LifeSpan BioSciences	LS-B5940-50	mouse
LifeSpan BioSciences	LS-C137501-100	mouse
LifeSpan BioSciences	LS-C31763-100	rabbit
LifeSpan BioSciences	LS-C99283-400	rabbit
LifeSpan BioSciences	LS-C9410-100	rabbit
LifeSpan BioSciences	LS-C122259-20	rabbit
LifeSpan BioSciences	LS-C88774-0.1	rabbit
LifeSpan BioSciences	LS-C136850-100	rabbit
LifeSpan BioSciences	LS-C96393-500	rabbit
LifeSpan BioSciences	LS-C193595-200	mouse
LifeSpan BioSciences	LS-C193596-100	mouse
LifeSpan BioSciences	LS-C63081-100	mouse
LifeSpan BioSciences	LS-C193597-100	mouse
LifeSpan BioSciences	LS-C169155-100	mouse
LifeSpan BioSciences	LS-C189569-1000	mouse
LifeSpan BioSciences	LS-C189635-1000	mouse
LifeSpan BioSciences	LS-C189636-1000	mouse
LifeSpan BioSciences	LS-C189634-1000	mouse
LifeSpan BioSciences	LS-C73947-500	mouse
LifeSpan BioSciences	LS-C189134-50	rabbit
LifeSpan BioSciences	LS-B5272-250	rabbit
LifeSpan BioSciences	LS-C176152-100	rabbit
LifeSpan BioSciences	LS-C194024-100	rabbit
LifeSpan BioSciences	LS-B5626-50	rabbit
LifeSpan BioSciences	LS-C131159-	rabbit

	20	
LifeSpan BioSciences	LS-B9287-200	rabbit
LifeSpan BioSciences	LS-C73949-200	rabbit
LifeSpan BioSciences	LS-C182368-50	rabbit
LifeSpan BioSciences	LS-B2411-50	goat
LifeSpan BioSciences	LS-B8326-100	mouse
LifeSpan BioSciences	LS-B7193-50	rabbit
LifeSpan BioSciences	LS-B425-50	rabbit
LifeSpan BioSciences	LS-C9413-100	rabbit
LifeSpan BioSciences	LS-B7193-50	rabbit
LifeSpan BioSciences	LS-C9413-100	rabbit
LifeSpan BioSciences	LS-B9080-100	rabbit
LifeSpan BioSciences	LS-C201116-100	rabbit
Boster Immunoleader	PA1431	
antibodies-online	ABIN933617	mouse
antibodies-online	ABIN1381708	Chicken
BACHEM	T-4816.0400	Rabbit
BACHEM	T-4815.0050	Rabbit
Biorbyt	orb12414	mouse
Biorbyt	orb128774	Rabbit
Biorbyt	orb12506	mouse
Biorbyt	orb94522	Rabbit
Biorbyt	orb13123	Rabbit
Biorbyt	orb88187	goat
Biorbyt	orb94961	mouse
Biorbyt	orb86662	rabbit
Biorbyt	orb170816	mouse
Biorbyt	orb175965	mouse
Biorbyt	orb19047	goat
Biorbyt	orb43142	rabbit
Biorbyt	orb120032	rabbit
Biorbyt	orb11192	rabbit
Biorbyt	orb11191	rabbit
antibodies-online	ABIN933617	mouse
BioVision	5426-100	mouse
BioVision	5422-100	mouse
BioVision	5424-100	mouse
BioVision	5423-100	mouse
BioVision	5425-100	mouse

BioVision	5421-100	mouse
Merck Millipore	04-970	mouse
Merck Millipore	MAB3055	rabbit
Merck Millipore	AB1870	Rabbit
Merck Millipore	AB10910	Rabbit
GenWay Biotech, Inc.	GWB-T00561	mouse
GenWay Biotech, Inc.	GWB-T00557	mouse
GenWay Biotech, Inc.	GWB-T00558	mouse
GenWay Biotech, Inc.	GWB-T00559	mouse
GenWay Biotech, Inc.	GWB-T00560	mouse
GenWay Biotech, Inc.	GWB-3A2E99	goat
GenWay Biotech, Inc.	GWB-23C38D	rabbit
GenWay Biotech, Inc.	GWB-295359	Rabbit
GenWay Biotech, Inc.	GWB-806785	Goat
Enzo Life Sciences, Inc.	ADI-905-629-100	mouse
Enzo Life Sciences, Inc.	ADI-905-630-100	mouse
Enzo Life Sciences, Inc.	ADI-905-500-1	Rabbit
Enzo Life Sciences, Inc.	ALX-210-309-R100	Rabbit
GeneTex	GTX28448	Rabbit
GeneTex	GTX37500	rabbit
GeneTex	GTX15489	rabbit
GeneTex	GTX89519	goat
Spring Bioscience	E3282	rabbit
Spring Bioscience	E3280	rabbit
Spring Bioscience	E3281	rabbit
Spring Bioscience	E3284	rabbit
Abbotec	251924	rabbit
Abbotec	250801	rabbit
MBL International	CY-P1035	
Rockland Immunochemicals, Inc.	100-401-404	Rabbit
Bioss Inc.	bs-0026R	Rabbit
Bioss Inc.	bs-0019R	Rabbit
Proteintech Group Inc	22952-1-AP	Rabbit

[00134]

[00135] Table 4: Non-limiting examples of commercially available ELISA Kits for integrin α_5 (ITGA5, Human)

Company Name	Catalogue number	Range	Sensitivity
antibodies-online	ABIN417612	0.156-10 ng/mL	0.054ng/mL
antibodies-online	ABIN365741	na	na
DLdevelop	DL-ITGa5-Hu	0.156-10ng/mL	0.054ng/mL
MyBioSource.com	MBS814027	na	na
R&D Systems	DYC3230-2	312-20,000 pg/mL	na
Biomatik	E91287Hu	0.156-10ng/mL	0.054ng/mL

[00136]

[00137] Table 5: Non-limiting examples of commercially available Antibodies for α_5 (ITGA5, human)

Company Name	Catalogue Number	Host
Novus Biologicals	NBP1-84576	rabbit
Biorbyt	orb69201	mouse
Abcam	ab72663	rabbit
Acris Antibodies GmbH	BM4033	mouse
Aviva Systems Biology	OAAF05375	rabbit
St John's Laboratory	STJ32097	mouse
GeneTex	GTX86915	rabbit
GeneTex	GTX86905	rabbit
OriGene Technologies	TA311966	rabbit
OriGene Technologies	TA310024	rat
Abbexa	abx15590	rabbit
Abbexa	abx15591	rabbit
Abbiotec	252937	mouse
Abnova Corporation	MAB10703	mouse
Abnova Corporation	MAB5267	mouse
Bioss Inc.	bs-0567R	rabbit
Cell Signaling Technology	4705S	rabbit
Atlas Antibodies	HPA002642	rabbit
GenWay Biotech, Inc.	GWB-MX190A	rabbit
GenWay Biotech, Inc.	GWB-D9743E	mouse
antibodies-online	ABIN656138	rabbit
antibodies-online	ABIN219716	rabbit
Novus Biologicals	NBP1-71421-0.1mg	rabbit
Novus Biologicals	NBP1-71421-0.05mg	rabbit
BioLegend	328009	mouse
BD Biosciences	610634	mouse
BioLegend	328002	mouse
BD Biosciences	610634	mouse
Abcam	ab72665	rabbit
Abcam	ab55988	rabbit

Bioworld Technology	BS7053	rabbit
Santa Cruz Biotechnology, Inc.	sc-166665	mouse
Bioworld Technology	BS7052	rabbit
R&D Systems	AF1864	goat
R&D Systems	FAB1864A	mouse
Thermo Scientific Pierce Antibodies	MA5-15568	mouse
Thermo Scientific Pierce Antibodies	MA1-81134	mouse
AbD Serotec (Bio-Rad)	MCA1187	mouse
AbD Serotec (Bio-Rad)	MCA1187T	mouse
Life Technologies	132600	mouse
Proteintech Group Inc	10569-1-AP	rabbit
Raybiotech, Inc.	119-14178	mouse
Creative Biomart	CAB-3671MH	mouse
Merck Millipore	CBL497	mouse
Fitzgerald Industries International	10R-1984	mouse
EMD Millipore	AB1921	rabbit
EMD Millipore	AB1949	rabbit

[00138]

[00139] Table 6: Non-limiting examples of commercially available ELISA Kits for β 1 (ITGB1, human)

Company Name	Catalogue number	Range	Sensitivity
antibodies-online	ABIN833710	na	na
Merck Millipore	ECM470	na	na
DLdevelop	DL-ITGb1-Hu	1.56-100ng/mL	na
Biomatik	E91042Hu	1.56-100ng/mL	0.64ng/mL

[00140] Table 7: Non-limiting examples of commercially available antibodies for β 1 ITGB1 (Human, Unconjugated)

Company Name	Catalogue number	Host
Abgent	AM2241b	mouse
Biorbyt	orb86390	rabbit
LifeSpan BioSciences	LS-C84969-100	mouse
Novus Biologicals	NB110-55545	rabbit
Abbexa	abx12778	rabbit
Bethyl Laboratories, Inc.	A303-735A	rabbit

Abcam	ab5189	Rabbit
St John's Laboratory	STJ60344	Rabbit
Cell Signaling Technology	4706S	Rabbit
Bioss Inc.	bs-0486R	Rabbit
Antigenix America Inc.	MA290020	
GenWay Biotech, Inc.	GWB-312F4D	mouse
Fitzgerald Industries International	20R-2722	rabbit
GeneTex	GTX50784	rabbit
Thermo Scientific Pierce Antibodies	MA1-80764	mouse
R&D Systems	AF1778	goat
Abbiotec	251162	rabbit
Bioworld Technology	BS1817	rabbit
Abgent	AM2241b	mouse
Enzo Life Sciences, Inc.	BML-IG6060-0100	mouse
BIOCARE MEDICAL	CME 386 A	rabbit
ProSci, Inc	48-392	Rabbit
eBioscience	14-0299-82	mouse

Table 8: Non-limiting Examples of commercially available antibodies for CD44 (human and unconjugated).

Company	Catalogue Number	Host
eBioscience	16-0441-81	Rat
Novus	NBP1-31121	Rabbit
Thermo	PA5-32327	Rabbit
Gentex	GTX50755	Rabbit
Cell Signaling	5640S	Mouse
Abcam	ab103552	Rabbit
Abnova	H00000960-M03	Mouse
antibodies-online	ABIN871672	Rabbit
R & D Systems	AF3660	Sheep
BD Biosciences	555476	Mouse
Abbiotec	252831	Mouse
Bethyl Laboratories	A303-872A	Rabbit
Proteintech Group	15675-1-AP	Rabbit
Enzo Life Sciences	ALX-801-089-C100	Mouse
Cell Science	852.603.020	
Merck Millipore	217594-100UL	Rat

Life Technologies	336700	Mouse
Santa Cruz	sc-53503	Mouse
ProSci	79-668	Rabbit
MP Biomedicals	08D526000	Mouse
Cedarlane	CLX47AP	Mouse

Table 9: Non-limiting examples of commercially available ELISA Kits for CD44.

Company	Catalogue Number
Cell Sciences	850.570.192
MyBioSource.com	MBS335446
Sino Biological	SEK12211
Biotrend Chemikalien	BMA-27215
Antibodies online	ABIN366268
Enzo Life Sciences	ALX-850-053-KI01
DRG International	EIA4876
Kamiya Biomedical Company	KT-032
abcam	AB45912-2
Novus	NBP1-87599
CUSABIO	CSB-E11846H

[00141] Antibodies directed against OPN, CD44 and integrins (α_5 , β_1 , β_3 , β_5) are included within the scope of this invention as they can be produced by well established procedures known to those of skill in the art. Additionally, any secondary antibodies, either monoclonal or polyclonal, directed to the first antibodies would also be included within the scope of this invention.

[00142] Polyclonal antibodies are preferably raised in animals by multiple subcutaneous (sc), intravenous (iv) or intraperitoneal (ip) injections of the relevant antigen with or without an adjuvant. It may be useful to conjugate the relevant antigen to a protein that is immunogenic in the species to be immunized, e.g., keyhole limpet hemocyanin, serum albumin, bovine thyroglobulin, or soybean trypsin inhibitor using a bifunctional or derivatizing agent, for example, maleimidobenzoyl sulfosuccinimide ester (conjugation through cysteine residues), N-hydroxysuccinimide (through lysine residues), glutaraldehyde, succinic anhydride, SOCl_2 , or $\text{R}_1\text{N}=\text{C}=\text{NR}$, where R and R1 are different alkyl groups.

[00143] Animals may be immunized against the antigen, immunogenic conjugates, or derivatives by combining the antigen or conjugate (e.g., 100 μg for rabbits or 5 μg for mice) with 3 volumes of

Freund's complete adjuvant and injecting the solution intradermally at multiple sites. One month later the animals are boosted with the antigen or conjugate (e.g., with 1/5 to 1/10 of the original amount used to immunize) in Freund's complete adjuvant by subcutaneous injection at multiple sites. Seven to 14 days later the animals are bled and the serum is assayed for antibody titer. Animals are boosted until the titer plateaus. Preferably, for conjugate immunizations, the animal is boosted with the conjugate of the same antigen, but conjugated to a different protein and/or through a different cross-linking reagent. Conjugates also can be made in recombinant cell culture as protein fusions. Also, aggregating agents such as alum are suitably used to enhance the immune response.

[00144] Monoclonal antibodies may be made using the hybridoma method first described by Kohler et al., Nature, 256: 495 (1975), or may be made by recombinant DNA methods (e.g., U.S. Patent No. 6,204,023). Monoclonal antibodies may also be made using the techniques described in U.S. Patent Nos. 6,025,155 and 6,077,677 as well as U.S. Patent Application Publication Nos. 2002/0160970 and 2003/0083293.

[00145] In the hybridoma method, a mouse or other appropriate host animal, such as a rat, hamster or monkey, is immunized (e.g., as hereinabove described) to elicit lymphocytes that produce or are capable of producing antibodies that will specifically bind to the antigen used for immunization. Alternatively, lymphocytes may be immunized in vitro. Lymphocytes then are fused with myeloma cells using a suitable fusing agent, such as polyethylene glycol, to form a hybridoma cell.

[00146] The hybridoma cells thus prepared are seeded and grown in a suitable culture medium that preferably contains one or more substances that inhibit the growth or survival of the unfused, parental myeloma cells. For example, if the parental myeloma cells lack the enzyme hypoxanthine guanine phosphoribosyl transferase (HGPRT or HPRT), the culture medium for the hybridomas typically will include hypoxanthine, aminopterin, and thymidine (HAT medium), which substances prevent the growth of HGPRT-deficient cells.

[00147] As used herein, the term "purified" in the expression "purified antibody" is simply meant to distinguish man-made antibody from an antibody that may naturally be produced by an animal against its own antigens. Hence, raw serum and hybridoma culture medium containing anti-OPN antibody are "purified antibodies" within the meaning of the present invention.

[00148] As used herein, the terminology "blood sample" is meant to refer to blood, plasma or serum.

[00149] As used herein, the terminology "cell sample" is meant to refer to a sample containing cells expressing the desired GPCR(s) in sufficient amount to detect a cellular response in order to classify the subject into one of functional groups FG1, FG2 and FG3. The cells in the cell sample may be any type of cells as long as they express the desired GPCR to be tested. The cells used herein naturally express one or more receptors coupled to G_i proteins and were selected in part for their accessibility for collection from subjects. Hence, cells such as osteoblasts, osteoclasts, peripheral blood mononuclear cell (PBMC) (inherently including principally lymphocytes but also monocytes) and myoblasts are advantageously accessible and may conveniently be used in the methods of the present invention. Blood cells (e.g., PBMCs, platelets (thrombocytes), etc.) in particular are particularly accessible and provide for a more rapid testing. Any blood cell can be used for the methods of the present invention so long as it possesses at least one GPCR receptor coupled to a G_i protein. The cells can be fresh or frozen and may or may not have been cultured (expanded) prior to testing. The "sample" may be of any origin including blood, saliva, tears, sputum, urine, feces, biopsy (e.g., muscle biopsy), as long as it contains cells expressing the desired GPCR(s).

[00150] The articles "a," "an" and "the" are used herein to refer to one or to more than one (i.e., to at least one) of the grammatical object of the article.

[00151] The term "including" and "comprising" are used herein to mean, and re used interchangeably with, the phrases "including but not limited to" and "comprising but not limited to".

[00152] The terms "such as" are used herein to mean, and is used interchangeably with, the phrase "such as but not limited to".

[00153] The present invention is illustrated in further details by the following non-limiting examples.

EXAMPLE 1

AIS ENDOPHENOTYPE AND BRACE TREATMENT OUTCOME

[00154] **METHODS:** A retrospective study was performed with 67 AIS patients having had a blood test (cell-based assay), seen between Jan 2007 and Nov 2012 and having completed treatment with TLSO braces respecting standard prescription criteria (23h per day). AIS patients were stratified

according to the method developed by Moreau et al. 2004 (Moreau et al., 2004; Akoume et al., 2010) based upon the measurement of a differential signaling impairment of receptors coupled to G inhibitory proteins (Gi) allowing their classification into three functional groups (i.e., biological endophenotypes FG1, FG2 or FG3). Cobb angles were measured by single blind observer in brace and at the end of treatment and compared to their initial values. Progression of the curvature was defined by 6° angle increase (Nachemson et al., 1995). Treatment was considered a success if final Cobb angle was $\leq 45^\circ$ or no surgery was required (Richards et al., 2005). Association between group classification and treatment outcome was analysed with Chi² test in a contingency table. Logistic regression models were performed for odds ratio calculation. Group comparability at time of prescription was verified using ANOVA and Chi² test: groups were not different on mean Cobb angle for all curves, Risser sign (i.e., amount of calcification of human pelvis as a measure of maturity) nor age.

[00155] **RESULTS:** The patient distribution is reported in Table 10 (15 in FG1, 27 in FG2, and 25 in FG3).

[00156] Table 10: Statistical analysis of the patient distribution comparing 3 success criteria (Cobb at the end of treatment $\leq 45^\circ$, Cobb angle progression $\leq 6^\circ$ and no need for surgery)

Final Cobb ≤ 45°				
	success	failure	Odds ratio	
FG1	6 (40%)	9 (60%)	1	
FG2	16 (59%)	11 (41%)	2.18	p=0.235
FG3	21 (84%)	4 (16 %)	7.88	p=0.007
Total	43 (64%)	24 (36%)	χ²=8,4 (p=0,015)	
Cobb angle progression ≤ 6°				
	success	failure	Odds ratio	
FG1	6 (40%)	9 (60%)	1	
FG2	13 (48%)	14 (52%)	1.39	p=0.612
FG3	15 (60%)	10 (40%)	2.25	p=0.224
Total	33 (49%)	34 (51%)	χ²=1,6 (p=0.444)	
No need for surgery				
	success	failure	Odds ratio	
FG1	8 (53%)	7 (47%)	1	
FG2	20 (74%)	7 (26%)	2.5	p=0.177
FG3	22 (88%)	3 (12%)	6.4	p=0.02
Total	50 (74%)	17 (25%)	χ²=5,96 (p=0.05)	

[00157] Globally, in all patients who had brace success, the majority were from FG2 and FG3. There was a clear association between the functional group and success of the treatment regarding the progression of curvature $\leq 45^\circ$ criteria. Group FG3 patients were more likely to have success with brace treatment than in group FG1. The association was in the same direction for group FG2. Regarding the $\geq 6^\circ$ of progression criteria, an increased proportion of success was noted in FG3. Success in treatment in regards to preventing surgery was statistically different between the groups ($\chi^2_{(2, 67)} = 5.96$, $p = 0.05$). It is 6.4 times more likely to prevent surgery than to have one in group FG3 compared to FG1 ($p=0.02$). Again, a tendency towards increased chance of preventing surgery was found in group FG2 compared to FG1.

[00158] In order to confirm the above results and determine whether the specific type of brace treatment used influenced outcome, a retrospective study was performed with 90 AIS patients previously stratified among three biological endophenotypes according to a cell-based assay, as described above, allowing their classification into three functional groups (FG1, FG2 or FG3). Patients completed the non-rigid/dynamic (SpineCor™) brace treatment following standard prescription criteria. Cobb angles were measured by a single blind observer in brace and at the end of treatment and compared to their initial values. Progression of the curvature was defined by a 6° Cobb increase and treatment was considered a success if final Cobb angle was $\leq 45^\circ$ or no surgery was required. Association between group classification and treatment outcome was analysed with χ^2 test. Logistic regression models were performed for odds ratio calculation. Group comparability at time of prescription was verified using ANOVA and χ^2 test: no differences for mean Cobb angle, Risser sign, BMI nor age.

[00159] **Results.** The patient distribution is reported in Table 11 (24 in FG1, 27 in FG2, and 39 in FG3). As for the first study with rigid brace treatment, globally, in all patients who had brace success, the majority were from FG3. There was a clear association between the functional group and the success of the treatment regarding the final Cobb angle $\leq 45^\circ$ criteria ($\chi^2 = 6.7$, $p = 0.034$) and in regards to preventing progression of 6° ($\chi^2 = 15.7$, $p < 0.001$). Being classified as FG3 was 4 times ($p=0.028$) and 7.6 times ($p=0.001$) more likely to lead to treatment success than failure compared to FG1, respectively for the $\leq 45^\circ$ final Cobb and $\leq 6^\circ$ progression criteria. There was no significant difference in treatment outcomes between groups FG1 and FG2.

[00160] Table 11: Statistical analysis of the patient distribution treated with SpineCor™ brace

comparing 2 success criteria (Cobb at the end of treatment $\leq 45^\circ$ and Cobb angle progression)

Final Cobb ≤ 45°				
	success	failure	Odds ratio	
FG1	15 (63%)	9 (37%)	1	
FG2	17 (63%)	10 (37%)	1.02	p=0.973
FG3	34 (87%)	5 (13 %)	4.08	p=0.028
Total	66 (73%)	24(27%)	χ²=6.7 (p=0.034)	
Cobb angle progression ≤ 6°				
	success	failure	Odds ratio	
FG1	5 (21%)	19 (79%)	1	
FG2	8 (30%)	19 (70%)	1.60	p=0.474
FG3	26 (67%)	13 (33%)	7.60	p=0.001
Total	39 (43%)	51 (57%)	χ²=15.7 (p<0.001)	

[00161] **Conclusion.** Globally, in all patients who had brace success, the majority were from FG2 and FG3. Outcomes of bracing were most favorable for patients presenting the FG3 endophenotype, independently of the type of bracing. There was a clear association between the functional group and success of the treatment regarding the progression of curvature $\leq 45^\circ$ criteria and the Cobb angle progression ≤ 6 . Furthermore, results showed a tendency towards increased chance of preventing Cobb angle progression (≤ 6) and surgery in group FG2 compared to FG1.

EXAMPLE 2

CIRCULATING OPN LEVEL VARIATIONS WITH AGE IN AIS AND CONTROL SUBJECTS

[00162] Data was obtained with AIS patients (N=884) in Phase 2 followed at Sainte-Justine Hospital, at the Shriners Hospital or Montreal Children's Hospital, in Montreal, Québec, Canada. Age matched control subjects (N=254) were recruited from primary and secondary schools in Montreal. The plasma was collected in tubes containing EDTA and circulating OPN levels were measured in blood samples from control and AIS subjects of age 9 to 18 by ELISA.

[00163] As shown in Figure 2, circulating OPN blood level generally increases until between the age of 11 and 12 years old and then begin to decrease with age. OPN levels are significantly higher in AIS than control subjects at all times and follow generally the same variation pattern with age.

EXAMPLE 3**CIRCULATING OPN LEVEL VARIATIONS UPON BRACE TREATMENT IN SUBJECTS HAVING HIGH AND LOW LEVELS OF OPN**

[00164] The effect of brace treatment on the level of circulating OPN in AIS subjects was studied. Data was obtained with AIS patients in Phase 2 followed at Sainte-Justine Hospital, at the Shriners Hospital or Montreal Children's Hospital, in Montreal, Québec, Canada. The plasma was collected in tubes containing EDTA and OPN was measured with ELISA (IBL International, catalogue # JP27158). Circulating OPN levels were measured in blood samples from control and AIS subjects every 6 months during four years. Subjects were separated in two groups. Figure 3A presents OPN levels for subjects which had initial (i.e., before the beginning of brace treatment) circulating OPN levels below 600 ng/mL, treated with a brace (N = 94) and age-matched untreated control subjects (N = 330). Figure 3B shows OPN levels for subjects which had initial circulating OPN levels $\geq$ 600 ng/ml, treated (N = 153) with a TLSO brace and age-matched untreated control subjects (N=310).

[00165] As shown in Figure 3A, in subjects having initial low levels of circulating OPN (i.e., below about 600 ng/ml), brace treatment first increased OPN levels. OPN levels were significantly higher in subjects treated with a brace 6 months after treatment and returned to the same level than subjects not treated with a brace after about 12 to 18 months of brace treatment. Brace treatment then induced a decrease in OPN levels which was maintained during the rest of the study, i.e., up to 48 months (Figure 3A).

[00166] In subjects having high levels of OPN at the beginning of the study (i.e., $\geq$ about 600 ng/ml), brace treatment had the opposite effect. It produced an important decrease in circulating OPN level within the first 6 months. Then, OPN level increased slowly until it reached about 600 ng/ml (i.e., about the same level as untreated subjects) about 24 months after the beginning of treatment and decreased again after. Circulating OPN levels remained below that of AIS subjects not treated with a brace, except for a short period around 24 months of treatment, where OPN levels reached a peak and overlapped with OPN levels of untreated subjects (Figure 2B).

[00167] Based on the results presented in Figure 3, it appears that when the treatment begins with circulating OPN levels below about 600 ng/mL, brace treatment generally first causes an increase in OPN production, whereas when treatment begins with OPN concentrations at or above this value, brace treatment induces a reduction in circulating levels of OPN. These results show that long term brace treatment generally decreases the circulating level of OPN and suggest the presence of a

retroinhibition mechanism which regulates circulating OPN levels when they reach around 600ng/ml.

EXAMPLE 4

ASSOCIATION BETWEEN OPN AND sCD44 LEVELS AND CURVE PROGRESSION IN AIS SUBJECTS ACCORDING TO THEIR FUNCTIONAL GROUP

[00168] The relation between curve progression and OPN and sCD44 levels was followed in AIS subjects. An association between OPN levels and curve progression was observed. In FG1 subjects, low levels of OPN ($\leq$ than about 500 ng/ml) correlated with curve progression (see for examples Figures 6, 8, 9 and 10) while high levels (e.g., at or above 1000 ng/ml) were generally associated with absence of curve progression or smaller rate of progression (see for example Figures 2 and 7). For FG2 and FG3 subjects, high levels of OPN were more often associated with curve progression (see for example Figure 17). Figures 4-19 shows examples of OPN and sCD44 levels variations observed with time and curve progression in AIS subjects for each functional group. No clear correlation was observed between curve progression and sCD44.

EXAMPLE 5

OPN ENHANCES GI-MEDIATED CELL SIGNALLING IN FG1 SUBJECTS AND DECREASES GI-MEDIATED SIGNALLING IN FG2 AND FG3 SUBJECTS

[00169] The variation in Gi-mediated cell signaling in response to OPN in each functional group (FG1, FG2 and FG3) was studied. Figures 20 and 21 show the response to OPN (increasing doses) on osteoblasts isolated from patients classified into functional groups FG1, FG2 and FG3. OPN enhances Gi signaling in the FG1 functional group and aggravates the impairment in the FG2 (hypersensitive) and FG3 (sensitive) functional groups (Figure 20). Furthermore, MC3T3-E1 cells were used to check the effect of the knockdown of OPN and its receptors. MC3T3-E1 osteoblasts cells were transiently transfected in serum-free medium, using Lipofectamine™ RNAiMAX reagent (Invitrogen) according to the manufacturer's instructions and functional experiments were performed 48h post transfection. Knock down of OPN expression in osteoblasts by siRNAs (CCA CAG CCA CAA GCA GUC CAG AUU A (SEQ ID NO: 14)) increases Gi-mediated transduction in FG2 and FG3 subgroups while it tends to decrease the response in FG1 (Figure 21).

[00170] The scope of the claims should not be limited by the preferred embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

EXAMPLE 6**DIFFERENTIAL EFFECT OF HA, CD44 AND INTEGRINS ON GI-MEDIATED CELL SIGNALLING IN FG1, FG2 AND FG3 FUNCTIONAL GROUPS.**

[00171] MC3T3-E1 cells were also used to check the effect of the knockdown of OPN's receptors by RNAi. Experimental conditions were as described for Example 5. The sequence of RNA oligonucleotides used for the knockdowns are: integrin β 1 (CCU AAG UCA GCA GUA GGA ACA UUA U (SEQ ID NO: 15)), integrin β 3 (CCU CCA GCU CAU UGU UGA UGC UUA U (SEQ ID NO: 16)); integrin β 5 (AGAAUGUCUGCUAAUCCACCCAAAA, HSS-105572, Life technologies (SEQ ID NO: 17), CUGAGGGCAAACCUUGUCAAAAUG, HSS-105573, Life technologies (SEQ ID NO: 18); and GAA AUGGCUUCAAAUCCAUAUAUACA, HSS-179984, life technologies, (SEQ ID NO: 19)) and CD44 (GAA CAA GGA GUC GUC AGA AAC UCC A (SEQ ID NO: 20)).

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CLAIMS:

1. A method of predicting brace treatment outcome in a subject in need thereof comprising classifying the subject into functional group FG1, FG2 or FG3, wherein the classification enables the prediction of brace treatment outcome.
2. The method of claim 1, wherein the classification of the subject into the FG2 or FG3 functional group is indicative that the subject is likely to benefit from brace treatment.
3. The method of claim 1, wherein the classification of the subject into the FG1 functional group is indicative that the subject is unlikely to benefit from brace treatment.
4. The method of claim 1, wherein the classification of the subject into the FG2 or FG3 functional group is indicative that the subject is likely to have a successful brace treatment.
5. The method of claim 1, wherein the classification of the subject into the FG1 functional group is indicative that the subject is unlikely to have a successful brace treatment.
6. The method of claim 1, wherein the classification of the subject into the FG2 or FG3 functional group is indicative that the subject has a decreased risk of curve progression following brace treatment.
7. The method of claim 1, wherein the classification of the subject into the FG1 functional group is indicative that the subject has an increased risk of curve progression following brace treatment.
8. The method of claim 1, wherein the classification of the subject into the FG2 or FG3 functional group is indicative that the subject has a decreased risk of requiring surgery following brace treatment.
9. The method of claim 1, wherein the classification of the subject into the FG1 functional group is indicative that the subject has an increased risk of requiring surgery following brace treatment.
10. The method of any one of claims 1-9, further comprising measuring the level of OPN in a blood sample from the subject prior to the beginning of brace treatment.
11. The method of claim 10, wherein the classification of the subject into the FG2 or FG3 functional group and a high level of OPN in the blood sample from the subject is indicative that the subject is further likely to benefit from brace treatment.

12. The method of claim 10, wherein the classification of the subject into the FG1 functional group and a high level of OPN in the blood sample from the subject is indicative that the subject is further unlikely to benefit from brace treatment.

13. The method of any one of claims 1-12, wherein the brace treatment comprises treatment with a Thoraco-Lumbo-Sacral-Orthosis (TLSO) brace, a Milwaukee brace, a Charleston brace, a SpineCor brace or any combination thereof.

14. The method of any one of claims 1-12, wherein the brace treatment comprises treatment with a Thoraco-Lumbo-Sacral-Orthosis (TLSO) brace or a SpineCor brace.

15. A method of predicting the risk of developing idiopathic scoliosis (IS) in a subject in need thereof comprising:

- i) classifying the subject into functional group FG1, FG2 or FG3; and
- ii) measuring the level of OPN in a blood sample from the subject,

wherein a classification of the subject into the FG1 functional group and a low level of OPN or a classification of the subject into the FG2 or FG3 functional group and a high level of OPN is indicative that the subject has an increased risk of developing IS.

16. The method of claim 15, wherein the risk of developing IS is a risk of curve progression.

17. A method of treating a subject in need thereof comprising classifying the subject into functional group FG1, FG2 or FG3, wherein

- i) when the subject is classified into the FG1 functional group, the subject is not treated with a brace; and
- ii) when the subject is classified into the FG2 or FG3 functional group, the subject is treated with a brace.

18. A method of treating a subject in need thereof comprising classifying the subject into functional group FG1, FG2 or FG3, wherein

- i) when the subject is classified into the FG1 functional group, the level of OPN or the activity of OPN in said subject is increased; and
- ii) when the subject is classified into the FG2 or FG3 functional group, the level of OPN or the activity of OPN in said subject is decreased.

19. The method of claim 18, wherein i) comprises treating said subject with:

- (a) OPN;
- (b) an OPN agonist;
- (c) a treatment or preventive measure which increases the level of circulating OPN;
- (d) an inhibitor of CD44 expression or activity; or
- (e) a combination of at least two of (a) to (d); and

and wherein ii) comprises treating said subject with:

- (f) an OPN antagonist;
- (g) a treatment or preventive measure which decreases the level of circulating OPN;
- (h) an inhibitor of integrin expression or activity;
- (i) sCD44 or a stimulator of CD44 expression; or
- (j) a combination of at least two of (f) to (i).

20. The method of claim 19, wherein the OPN agonist is (b i) HA; (b ii) an OPN functional fragment; (b iii) an OPN functional derivative; or (b iv) a combination of at least two of (b i) to (b iii).

21. The method of claim 19, wherein the treatment or preventive measure which increases the level of circulating OPN comprises applying pulsative compressive pressure for 15-90 minutes on at least one body part of said subject.

22. The method of claim 19 or 20, wherein the treatment or preventive measure which increases the level of circulating OPN comprises applying low intensity pulse ultrasound (LIPUS).

23. The method of any one of claims 19-22, wherein the inhibitor of CD44 expression or activity is an antibody which binds to CD44 or a siRNA or antisense specific for CD44.

24. The method of any one of claims 19-23, wherein the OPN antagonist is (f i) melatonin; (f ii) selenium; (f iii) an antibody which binds to OPN; (f iv) an siRNA or antisense specific for OPN; (f v) a molecule that blocks the binding of OPN to integrins; or (f vi) a combination of at least two of (f i) to (f vi).

25. The method of any one of claims 19-24, wherein the treatment or preventive measure which decreases the level of circulating OPN is: (g i) brace treatment; (g ii) accupoint heat sensitive moxibustion; (g iii) heat therapy with pad; (g iv) electroacupuncture; (g v) thermal bath; or (g vi) a combination of at least two of (g i) to (g v).

26. The method of claim 24, wherein the molecule that blocks the binding of OPN to integrins is a RGD peptide or derivative thereof.
27. The method of claim 24, wherein the molecule that blocks the binding of OPN to integrins is a peptide fragment of OPN comprising a RGD motif.
28. The method of claim 27, wherein the peptide fragment of OPN comprises the amino acid sequence GRGDSVYGLRS (SEQ ID NO: 13).
29. The method of any one of claims 19-28, wherein the inhibitor of integrin activity is (h i) an antibody that binds specifically to integrin subunit α_5 ; (h ii) an antibody that binds specifically to integrin subunit β_1 ; (h iii) an antibody that binds specifically to integrin subunit β_3 ; (h iv) an antibody that binds specifically to integrin subunit β_5 ; (h v) an antibody that binds specifically to integrin subunits $\alpha_5\beta_1$; or (h vi) a combination of at least two of (h i) to (h v).
30. The method of any one of claims 19-28, wherein the inhibitor of integrin activity is volociximabTM; ATN-161, etaratuzumabTM, etaracizzumabTM, VitaxinTM, MEDI-522, CNT095 or CilengitideTM.
31. The method of any one of claims 19-28, wherein the inhibitor of integrin activity is volociximabTM or CilengitideTM.
32. The method of any one of claims 19-31, wherein the integrin is $\alpha_5\beta_1$.
33. The method of any one of claims 19-32, wherein the inhibitor of integrin expression is (h i) an siRNA or antisense specific to integrin subunit α_5 ; (h ii) an siRNA or antisense specific to integrin subunit β_1 ; (h iii) an siRNA or antisense specific to integrin subunit β_3 ; (h iv) an siRNA or antisense specific to integrin subunit β_5 ; (v) a combination of at least two of (h i) to (h vi).
34. The method of any one of claims 18 to 33, further comprising treating the subject with a brace.
35. The method of any one of claims 19-34, further comprising measuring the level of OPN in a blood sample from the subject periodically.
36. The method of claim 35, wherein the level of OPN is measured once a month.

37. The method of any one of claims 11, 12, 15 and 16, wherein the high level of OPN in the blood sample of the subject is between about 600-1000 ng/ml.
38. The method of claim 15 or 16, wherein the low level of OPN in the blood sample of the subject is ≤ 500 ng/ml.
39. The method of any one of claims 1-38, wherein the subject is a pediatric subject.
40. The method of any one of claims 1-39, wherein classifying the subject comprises determining changes in cellular impedance following Gi-stimulation in a cell sample from the subject.
41. The method of claim 40, wherein the cellular impedance is measured by cellular dielectric spectroscopy (CDS).
42. The method of any one of claims 1-39, wherein classifying the subject comprises measuring changes in cAMP concentration following Gi-stimulation in a cell sample from the subject.
43. The method of any one of claims 1-39, wherein classifying the subject comprises determining the phosphorylation pattern of Gi α proteins in a cell sample from the subject.
44. The method of any one of claims 1-39, wherein classifying the subject comprises determining cellular proliferation of a cell sample from the subject.
45. The method of any one of claims 1-44, wherein the subject is a subject diagnosed with idiopathic scoliosis (IS).
46. The method of claim 45, wherein the IS is adolescent idiopathic scoliosis (AIS).
47. A kit for predicting brace treatment outcome in a subject suffering from Idiopathic Scoliosis comprising reagents for classifying a subject into functional group FG1, FG2 or FG3.
48. A kit for predicting the risk of developing severe Idiopathic Scoliosis comprising reagents for classifying a subject into functional group FG1, FG2 or FG3.
49. The kit of claim 47 or 48, comprising at least two of:
- a) a ligand for Gi stimulation;

- b) a ligand for detecting G α proteins phosphorylation; and
- c) reagents for detecting cellular proliferation.

50. The kit of claim 49, further comprising:

- d) a ligand for Gs stimulation;
- e) reagents for detecting the level of OPN; and/or
- f) instructions for predicting brace treatment outcome.

FIGURE 1

Functional group	Effect of OPN	Initial Circulating [OPN]	Brace treatment	Other treatment options (See also Figure 1B)
FG1	Protective	high	No	increase OPN level or activity (e.g., OPN, OPN agonist, Treatment and preventive measures which increase OPN levels)
		low	Generally no	Increase OPN level or activity (e.g., OPN, OPN agonist, Treatment and preventive measures which increase OPN levels)
FG2	Risk factor	high	Yes	Decrease OPN level or activity (e.g., OPN antagonist, Treatment and preventive measures which decrease OPN levels)
		low	Yes,	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels)
FG3	Risk factor	high	Yes	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels)
		low	Yes	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels)

FIGURE 1 (Continued)

B

Treatment or preventive measure	Functional group			Comments
	FG1	FG2	FG3	
Increase sCD44 level	no	yes	yes	Decreases OPN's bioavailability to integrins (e.g., $\alpha_5\beta_1$)
Increase HA level (e.g., supplements or HA-rich diet)	yes	avoid	avoid	HA increases OPN's bioavailability
Decrease HA level (e.g., HA-poor diet)	avoid	yes	yes	HA increases OPN's bioavailability
Massages (e.g., pulsative compressive pressure, LIPUS)	yes	avoid	avoid	Increase OPN level (see US 13/822,982)
acupoint heat sensitive moxibustion; heat therapy with pad; electroacupuncture, thermal bath	no	yes	yes	Decrease plasma OPN levels
Src inhibitors	--	yes	yes	Involved in the activation of PIPK1 γ
FAK inhibitors	--	yes	yes	Involved in the activation of PIPK1 γ
RGD peptides	--	yes	yes	Inhibit the binding of OPN to integrins
Decreasing PIPK1 γ level or activity (e.g., inhibitors)	--	yes	yes	Increases binding of integrins to OPN
Increasing the level or activity of PTP μ	--	yes	yes	Involves in the dephosphorylation (inhibition) of PIPK1 γ
Early corrective surgery (before reaching 45 degree Cobb angle)	no	yes,	no	Especially if OPN levels are high and/or remain high, FG2 subjects have an increased risk of severe scoliosis

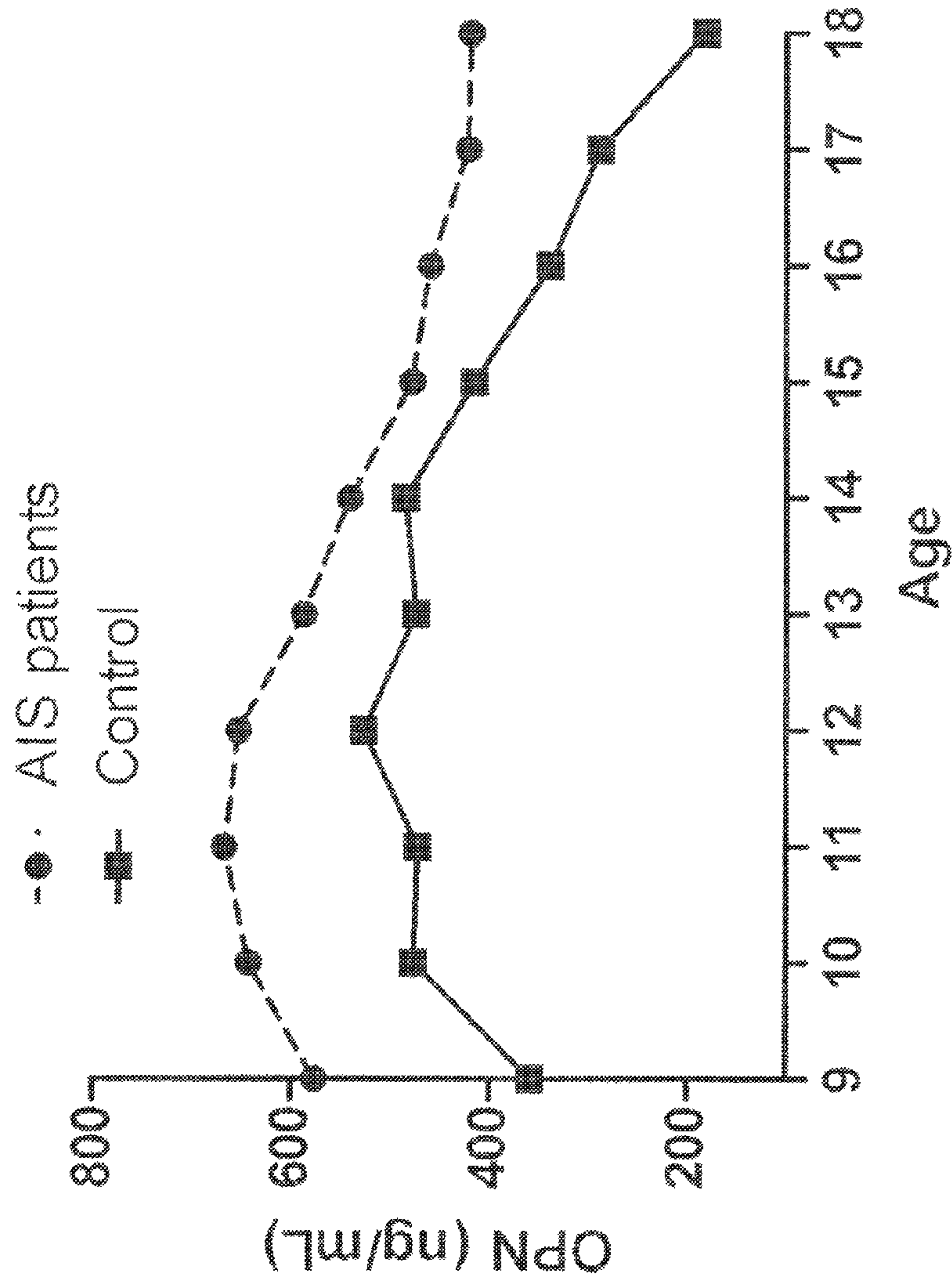


Figure 2

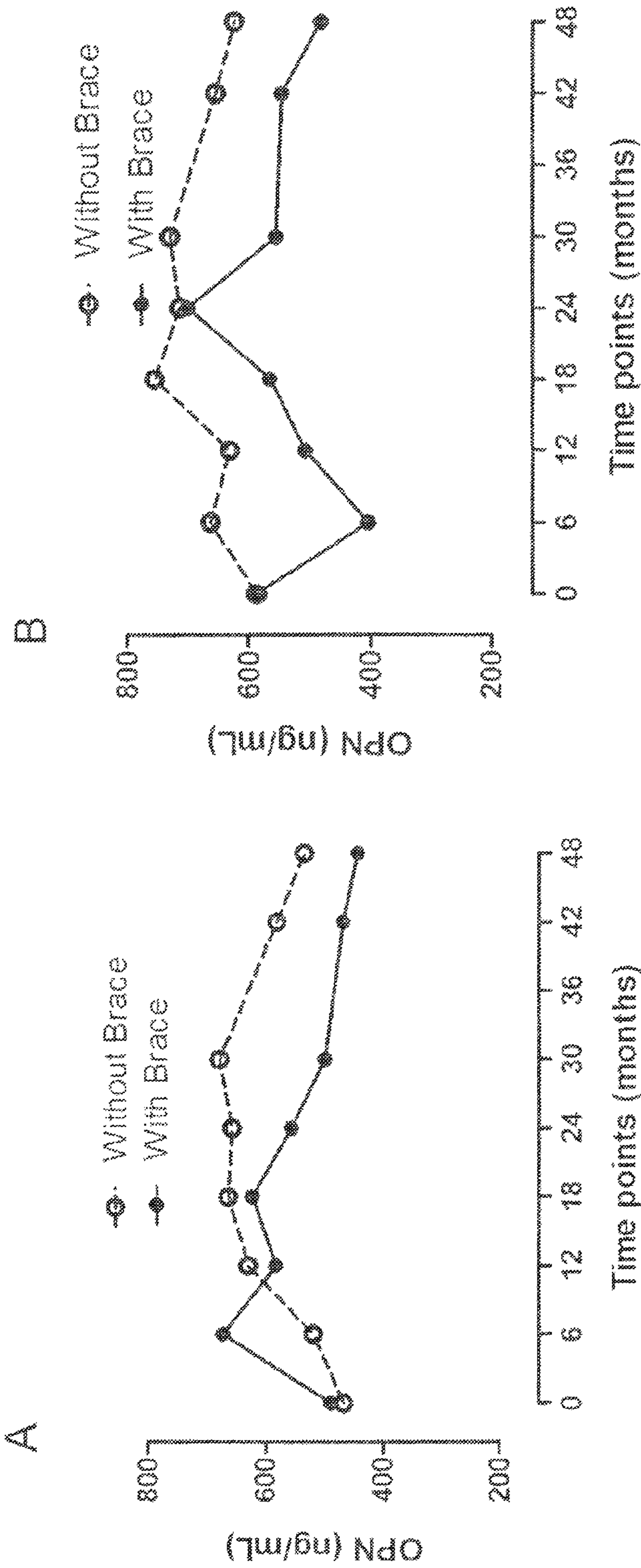
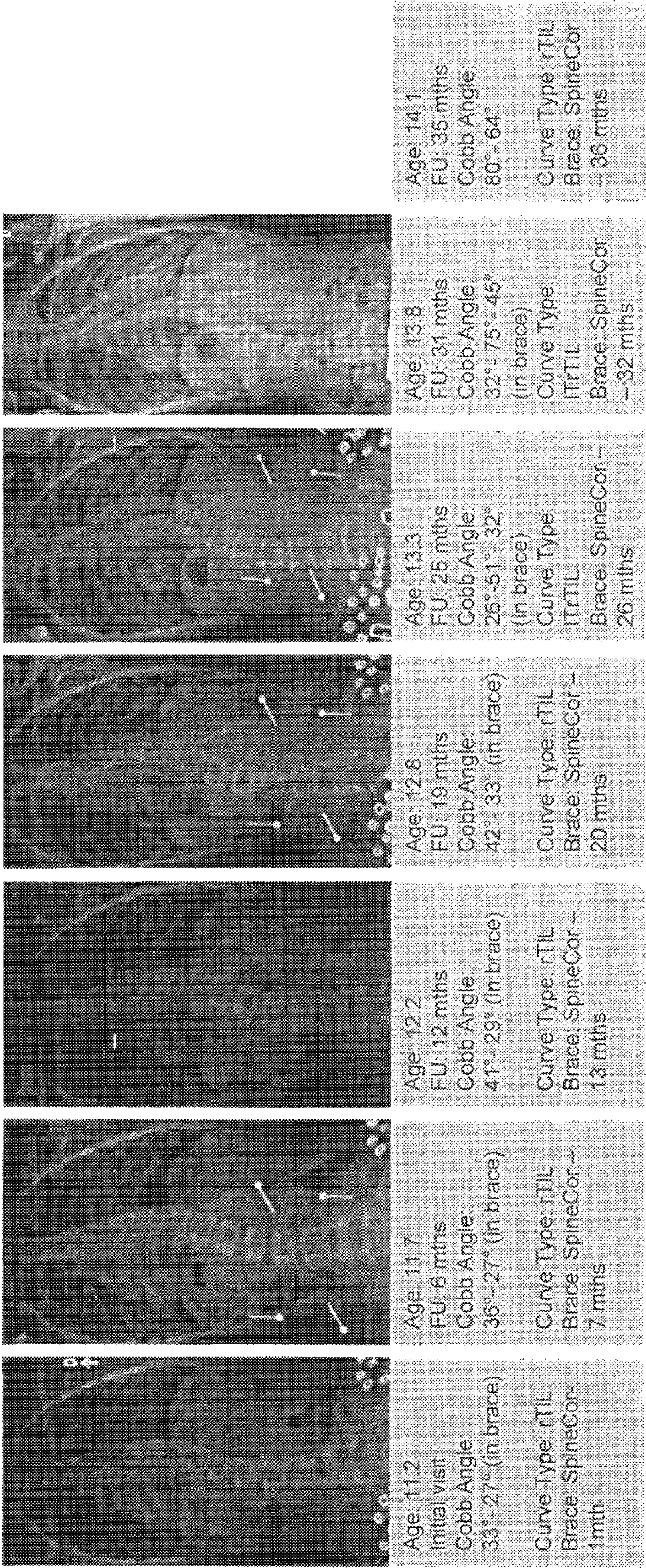


Figure 3

Clinical Trial Results – Case #593 (F)

Predictive Diagnostics

A



Functional Group 1

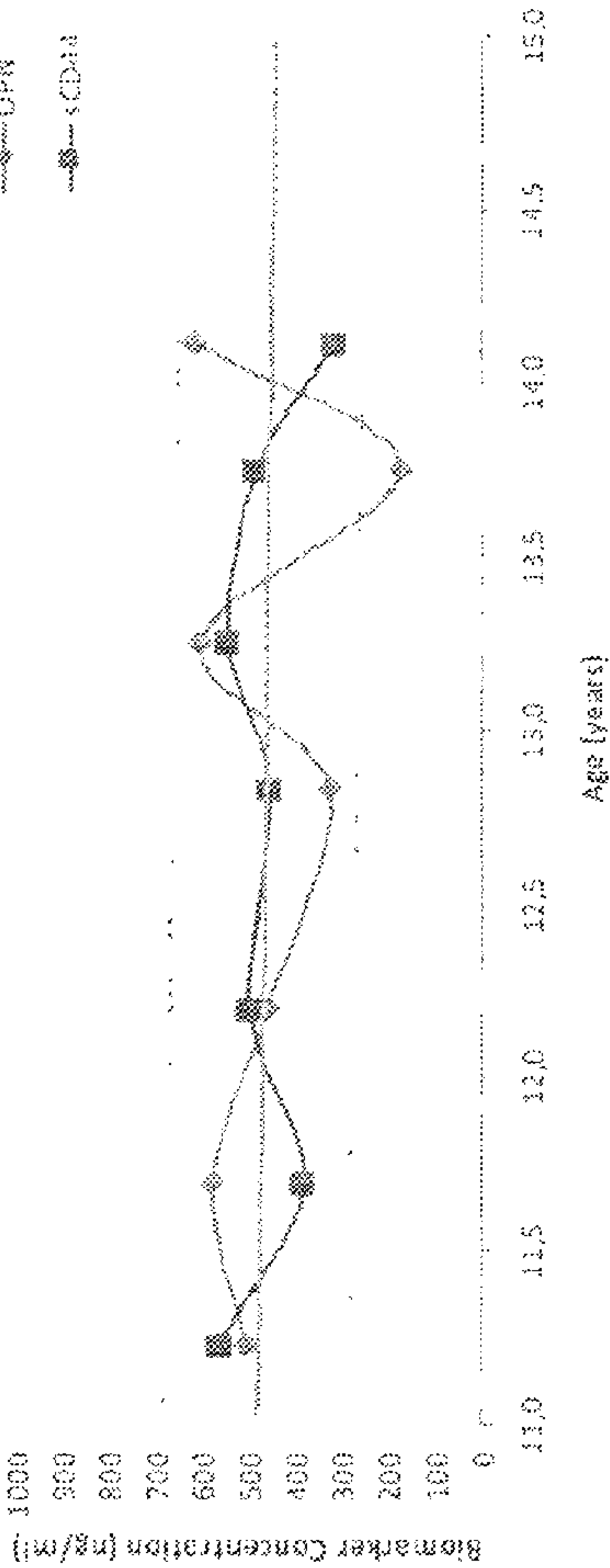
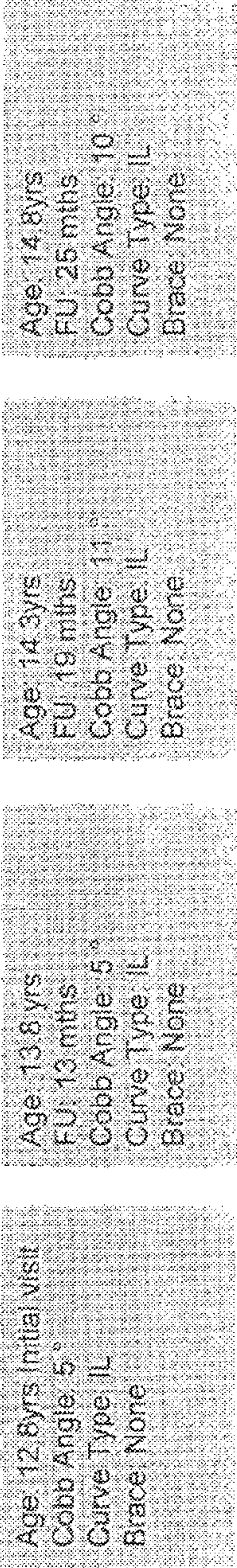
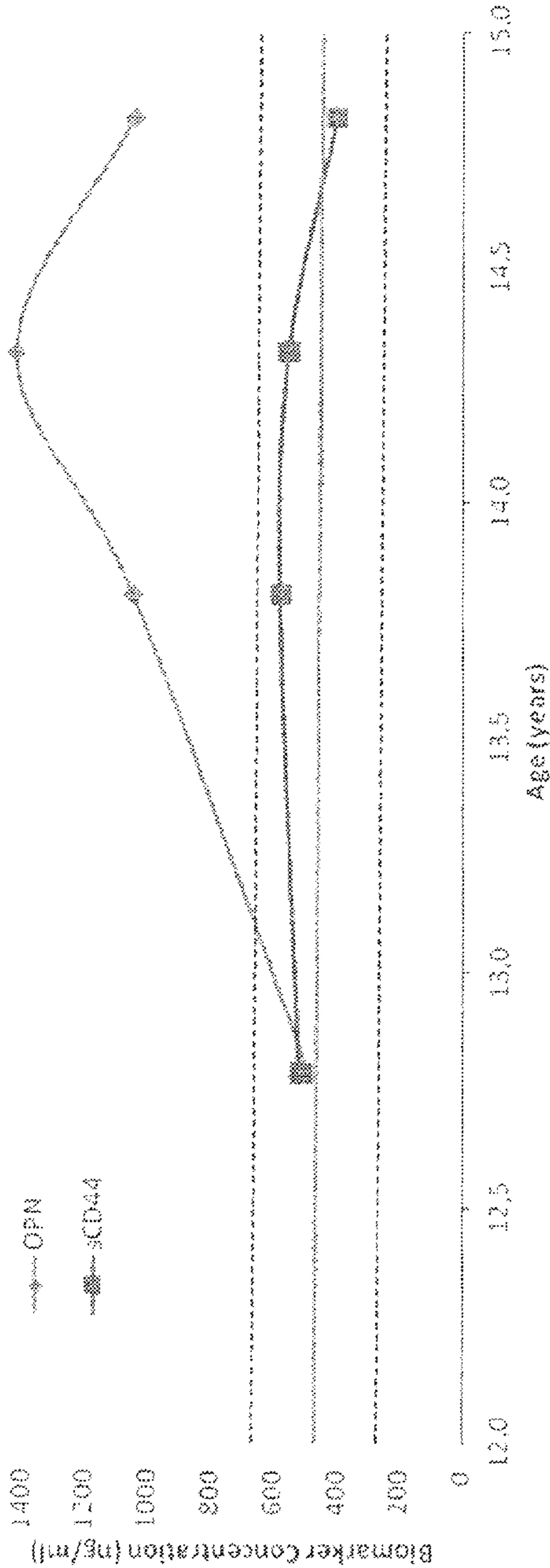


Figure 4

Clinical Trial Results – Case #148 (F)

Predictive Diagnostics

Functional
Group
1



High OPN, no progression over 25 months

Figure 5

Clinical Trial Results – Case #393 (M)

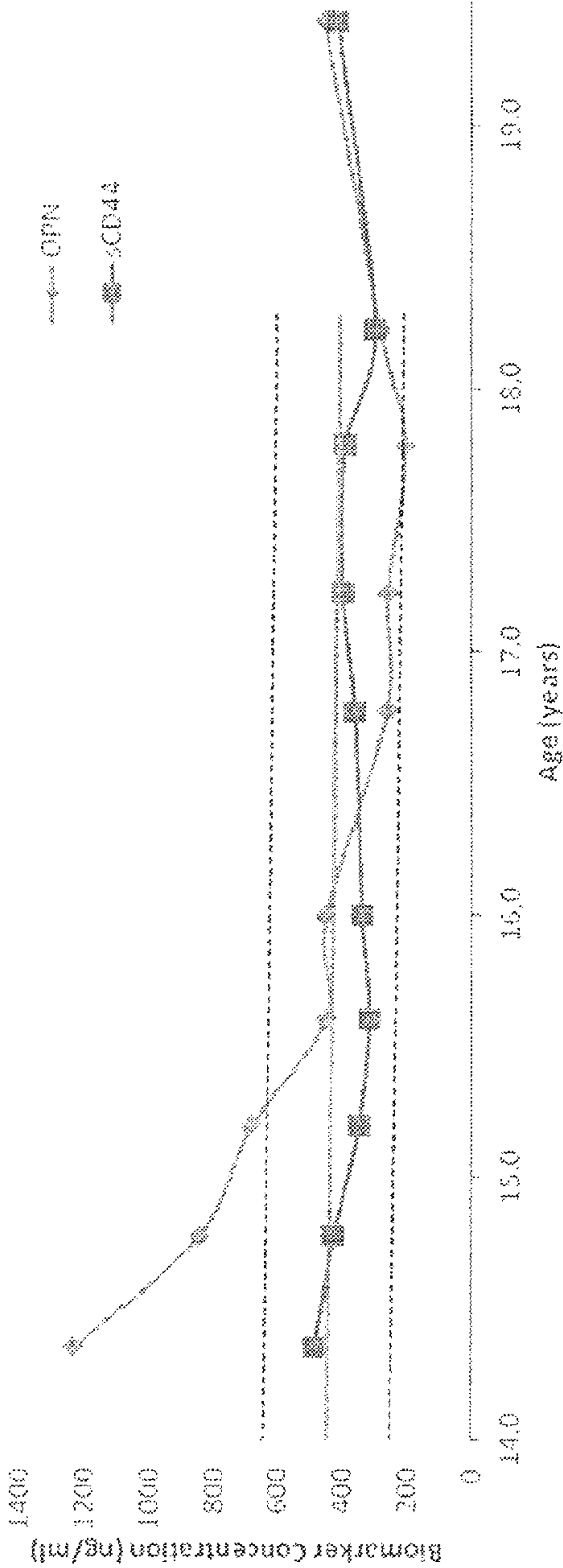
Predictive Diagnostics

Functional

Group

1

A



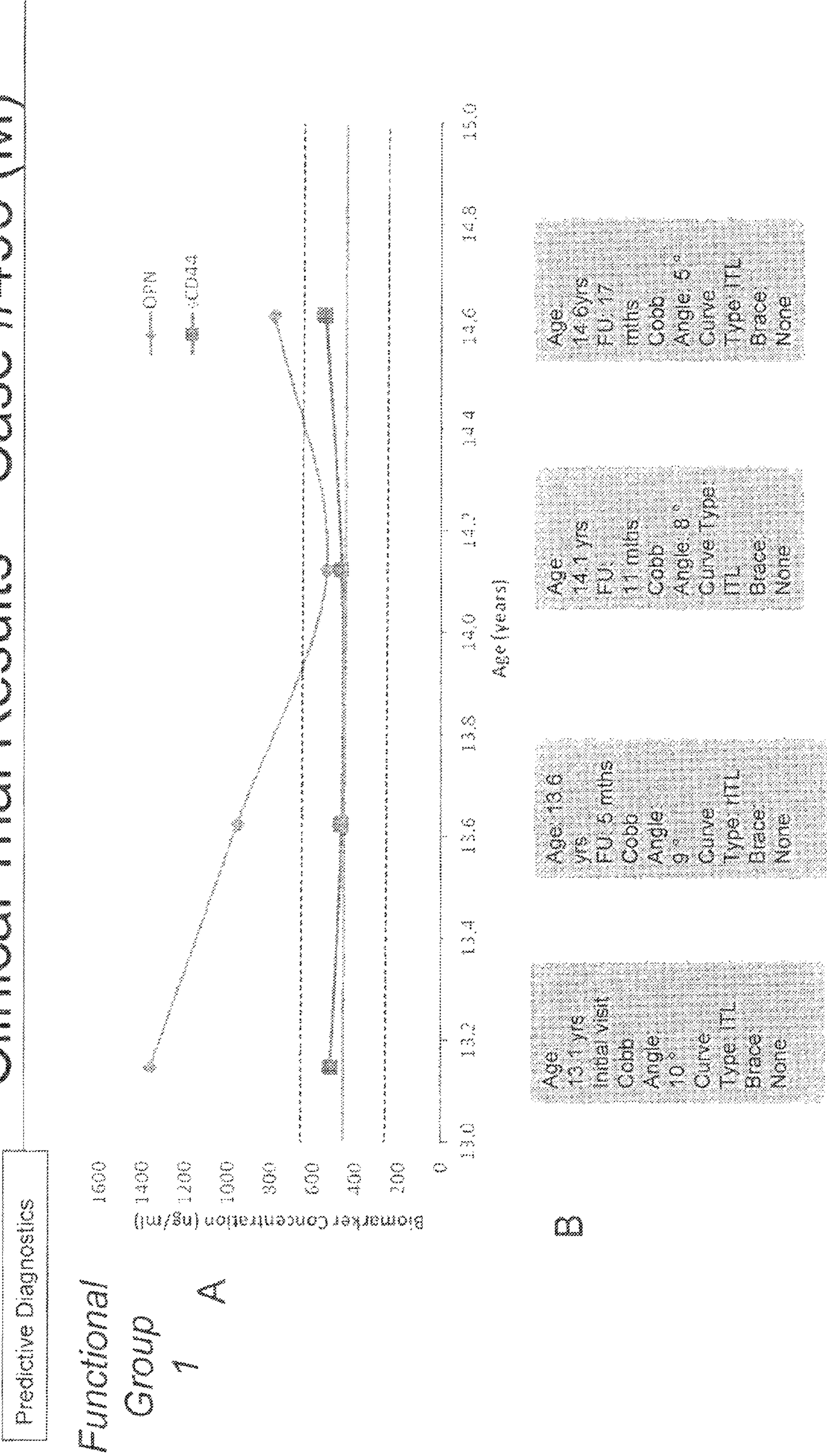
B

Age: 14.3yrs	Age: 14.8yrs	Age: 15.2yrs	Age: 15.6yrs	Age: 16.0yrs	Age: 16.8yrs	Age: 17.2yrs	Age: 17.8yrs	Age: 18.2yrs	Age: 19.4yrs
Initial visit	5 mths	10 mths	15 mths	19 mths	29 mths	34 mths	41 mths	46 mths	60 mths
Cobb Angle: 26-15°	Cobb Angle: 27-19°	Cobb Angle: 27-34-19°	Cobb Angle: 27-34-19°	Cobb Angle: 30-36-21°	Cobb Angle: 29-34-20°	Cobb Angle: 35-36-23°	Cobb Angle: 30-36-18°	Cobb Angle: 34-17°	Cobb Angle: 35-38°
Curve Type: rTIL	Curve Type: rTIL	Curve Type: rTIL	Curve Type: rTIL	Curve Type: rTIL	Curve Type: rTIL	Curve Type: rTIL	Curve Type: rTIL	Curve Type: rTIL	Curve Type: rTIL
Brace: None	Brace: None	Brace: Boston-4mths	Brace: Boston-8mths	Brace: Boston-8mths	Brace: Boston-18mths	Brace: Boston-23mths	Brace: Boston-30mths	Brace: None	Brace: None
None	None	None	None	None	None	None	None	None	None

Drop in OPN, progression over 5 years

Figure 6

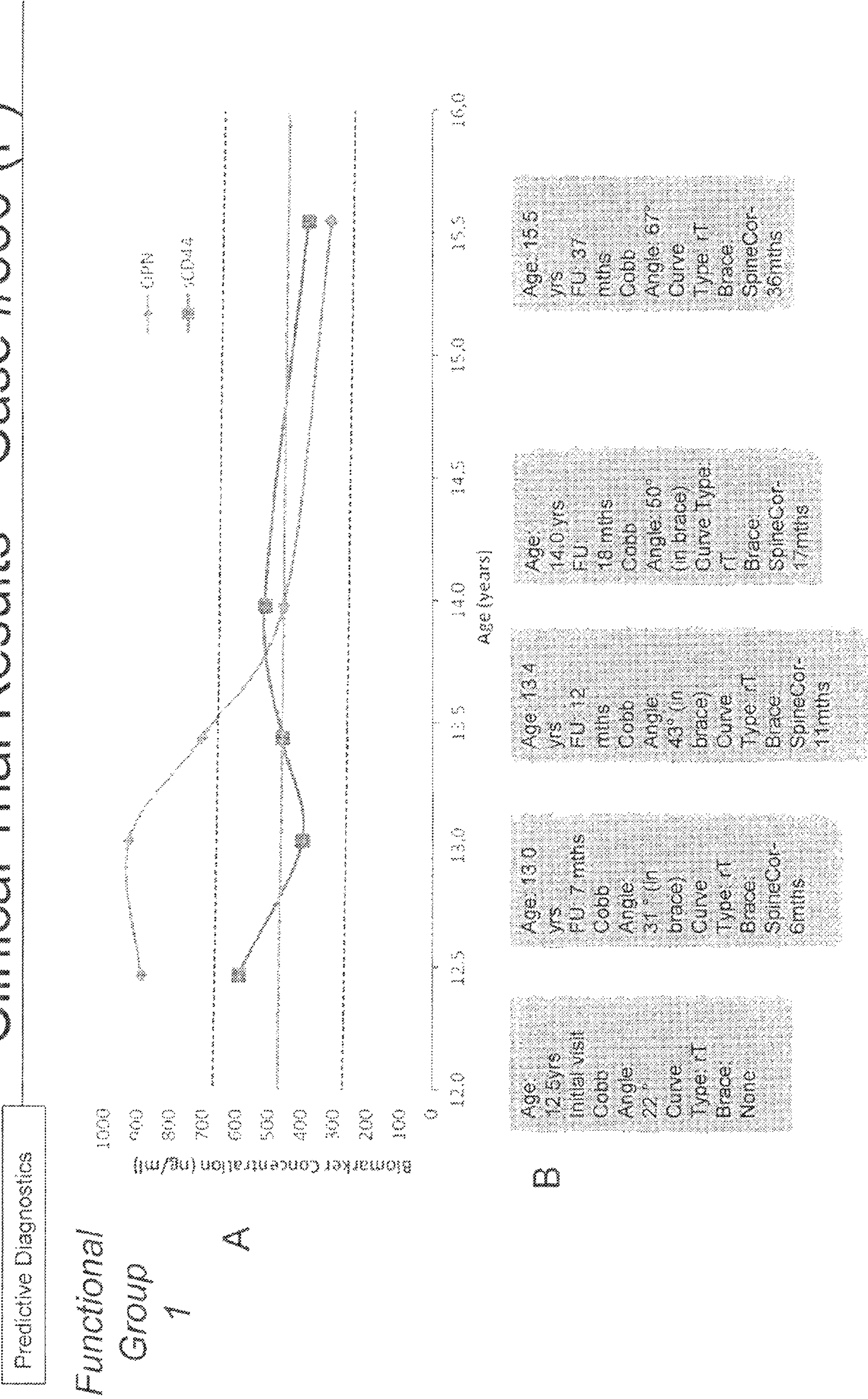
Clinical Trial Results – Case #498 (M)



High OPN, no progression over 17 months

Figure 7

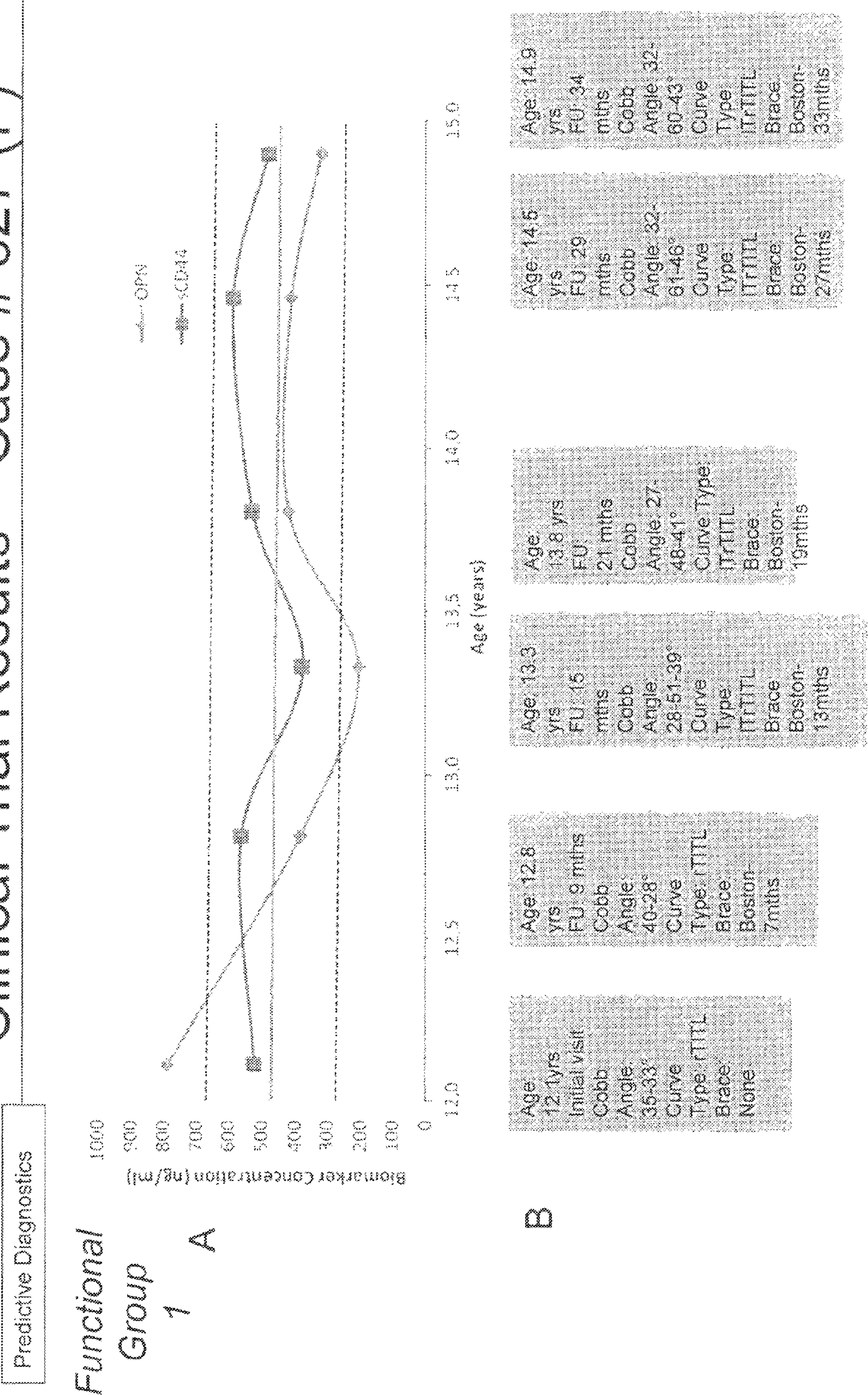
Clinical Trial Results – Case #530 (F)



Drop in OPN, progression over 37 months

Figure 8

Clinical Trial Results – Case # 627 (F)



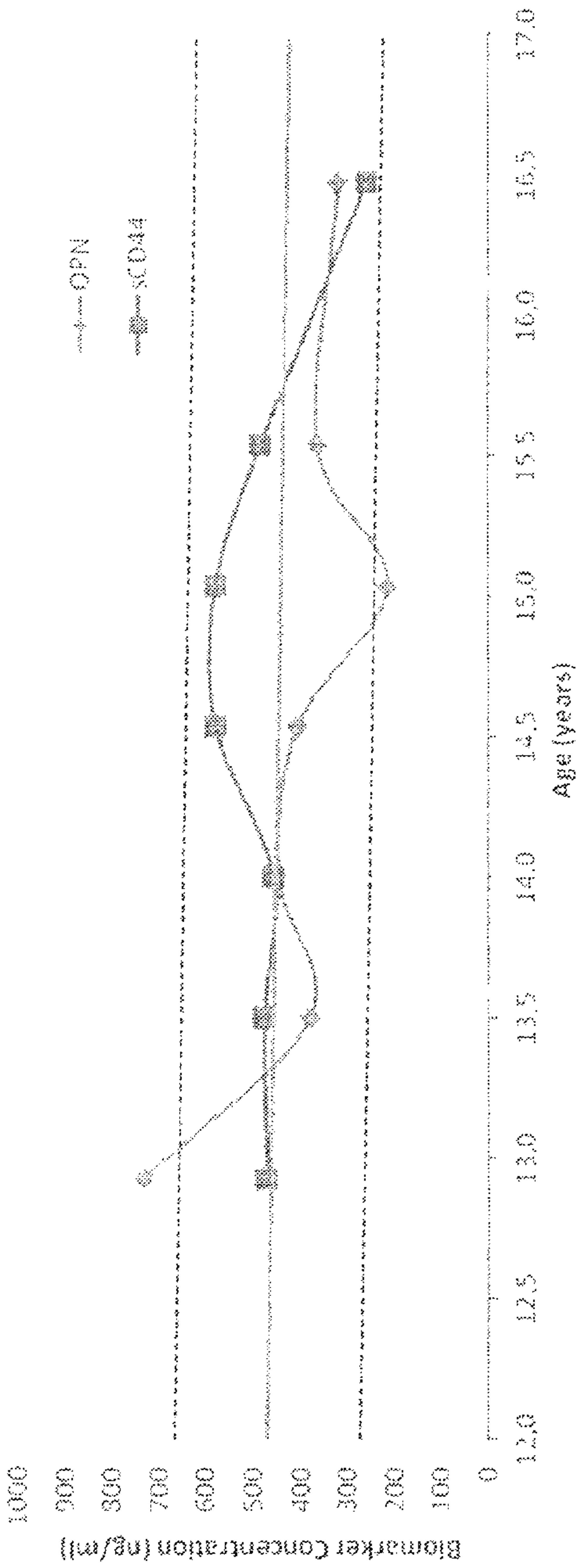
Drop in OPN, progression over 34 months

Figure 9

Clinical Trial Results – Case # 675 (F)

Predictive Diagnostics

Functional Group 1



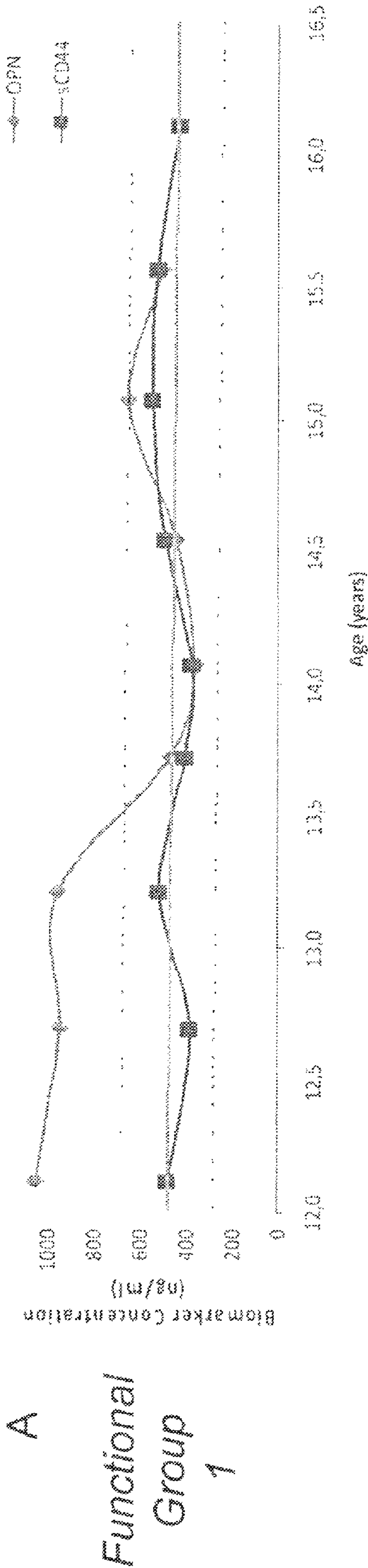
B

Age: 12.9yrs	Age: 13.5	Age: 14.0	Age: 14.5yrs	Age: 15.0	Age: 15.5	Age: 16.0	Age: 16.5
Initial visit	yrs	yrs	14.5 yrs	yrs	yrs	yrs	yrs
Cobb	FU: 7 mths	FU: 10	FU	FU: 25	FU: 31	FU: 42	FU: 42
Angle:	Cobb	mths	19 mths	mths	mths	mths	mths
37°	Angle:	Cobb	Cobb	Cobb	Cobb	Cobb	Cobb
Curve	37°	Angle	Angle: 40°	Angle: 41°	Angle: 47°	Angle: 47°	Angle: 47°
Type: rT	Curve	39°	Curve Type:	Curve	Curve	Curve	Curve
Brace	Type: rT	Curve	rT	Type: rT	Type: rT	Type: rT	Type: rT
None	Brace	Brace:	Brace	Brace:	Brace:	Brace:	Brace:
	Boston-	Boston-	Boston-	None	None	None	None
	6mths	12mths	18mths				

Drop in OPN, progression over 42 months
Figure 10

Clinical Trial Results – Case #394 (F)

Predictive Diagnostics



B

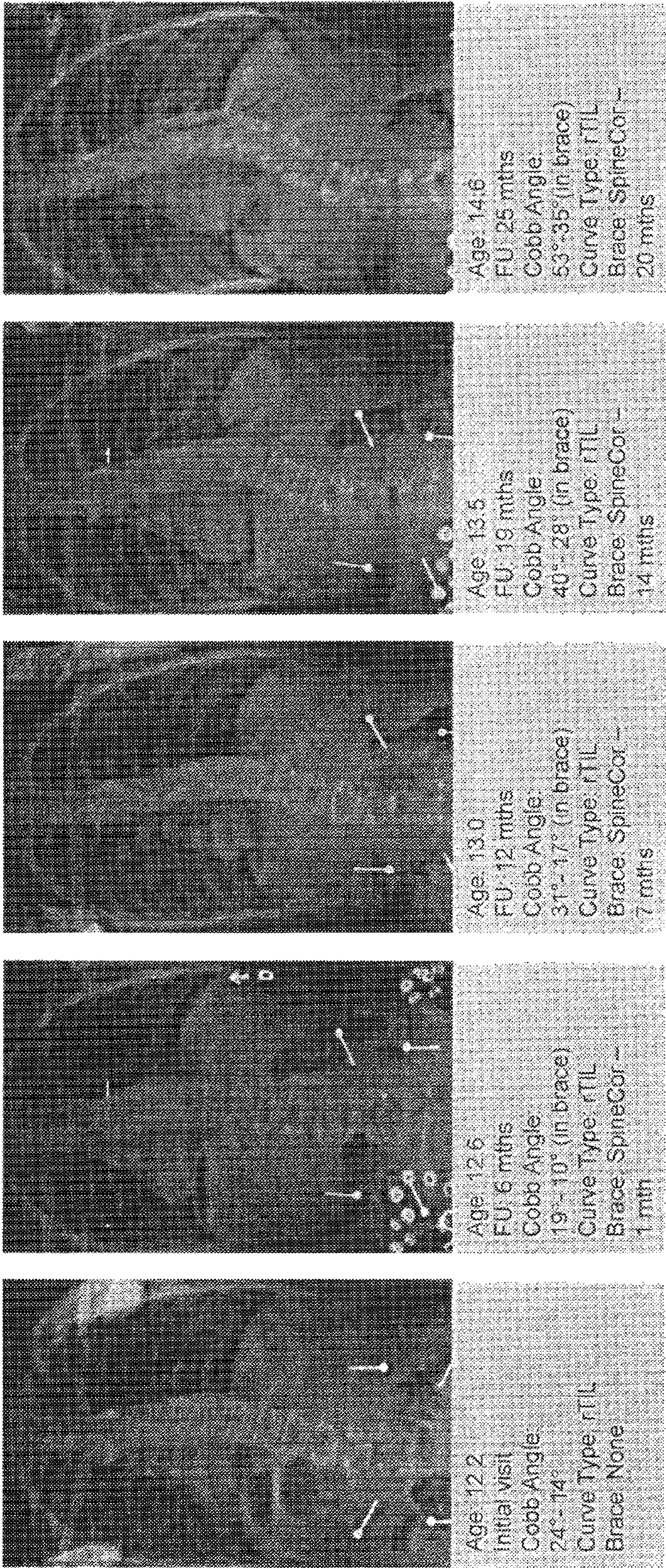
Age: 12.1yrs Initial visit Cobb Angle: 17-35-27° Curve Type: ITrTIL Brace: None	Age: 12.7yrs FU: 7 mths Cobb Angle: 17-31-30° Curve Type: ITrTIL Brace: Boston- 6mths	Age: 13.2yrs FU: 13 mths Cobb Angle: 25-36-32° Curve Type: ITrTIL Brace: Boston-12 mths	Age: 13.7yrs FU: 19 mths Cobb Angle: 27-45-28° Curve Type: ITrTIL Brace: Boston- 18mths	Age: 14.1yrs FU: 24 mths Cobb Angle: 28-44-28° Curve Type: ITrTIL Brace: Boston- 23mths	Age: 14.6yrs FU: 29 mths Cobb Angle: 27-49-29° Curve Type: ITrTIL Brace: Boston- 28mths	Age: 15.1yrs FU: 36 mths Cobb Angle: 25-46-27° Curve Type: ITrTIL Brace: Boston- 35mths	Age: 15.6yrs FU: 42 mths Cobb Angle: 26-43-28° Curve Type: ITrTIL Brace: Boston- 41mths	Age: 16.1yrs FU: 48 mths Cobb Angle: 25-45-27° Curve Type: ITrTIL Brace: Boston- 47mths
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Figure 11

Clinical Trial Results – Case #679 (F)

Predictive Diagnostics

A



Functional Group 1

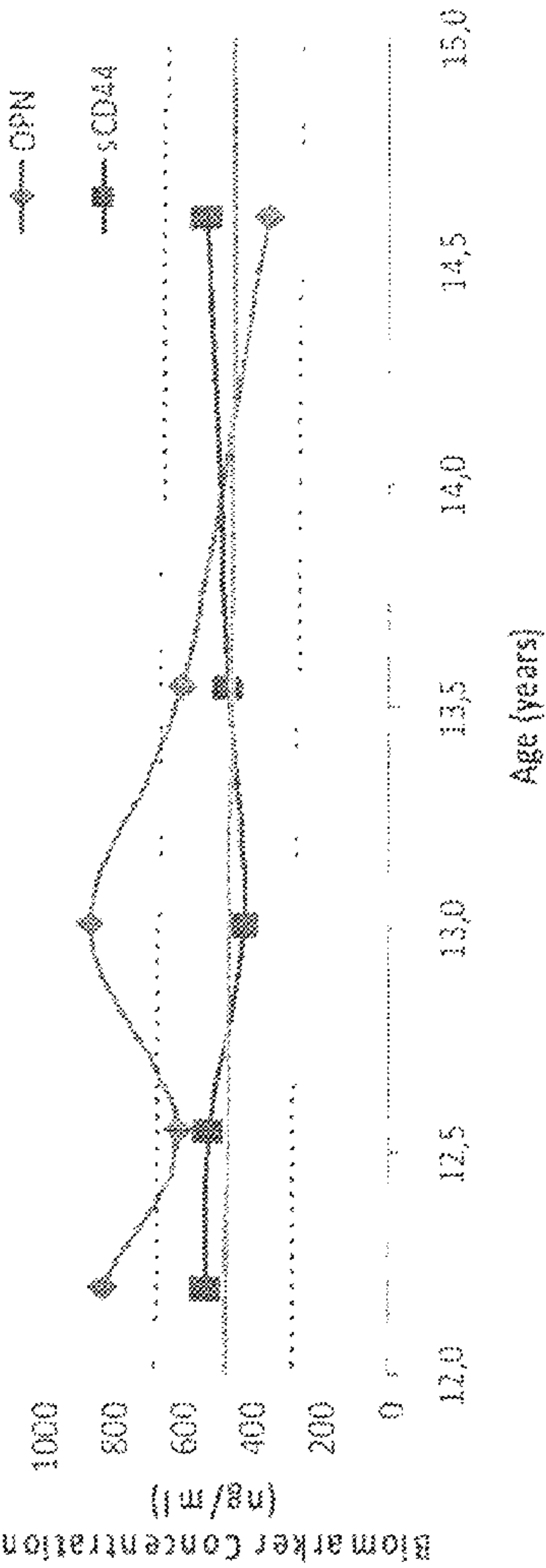
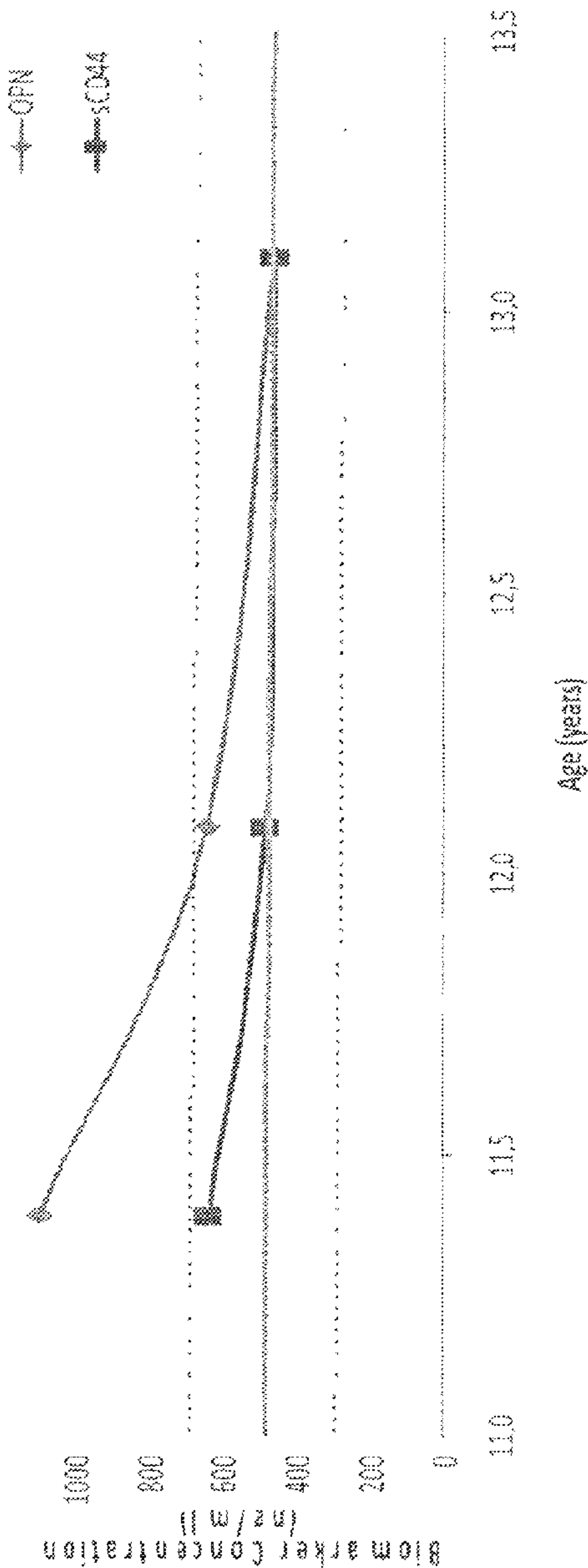


Figure 12

Clinical Trial Results – Case #460 (F)

Predictive Diagnostics



B

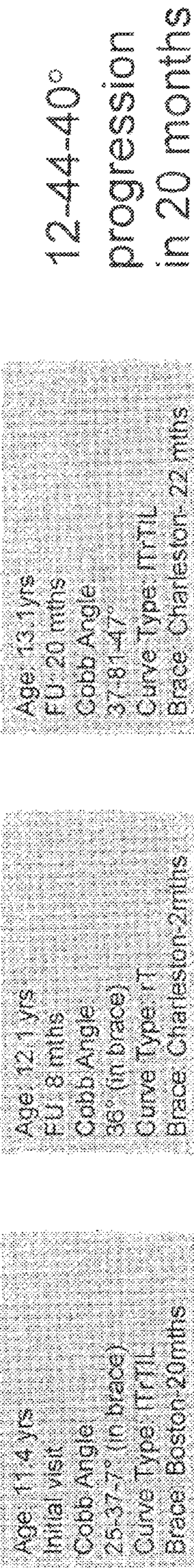


Figure 13

Clinical Trial Results – Case #789 (F)

Predictive Diagnostics

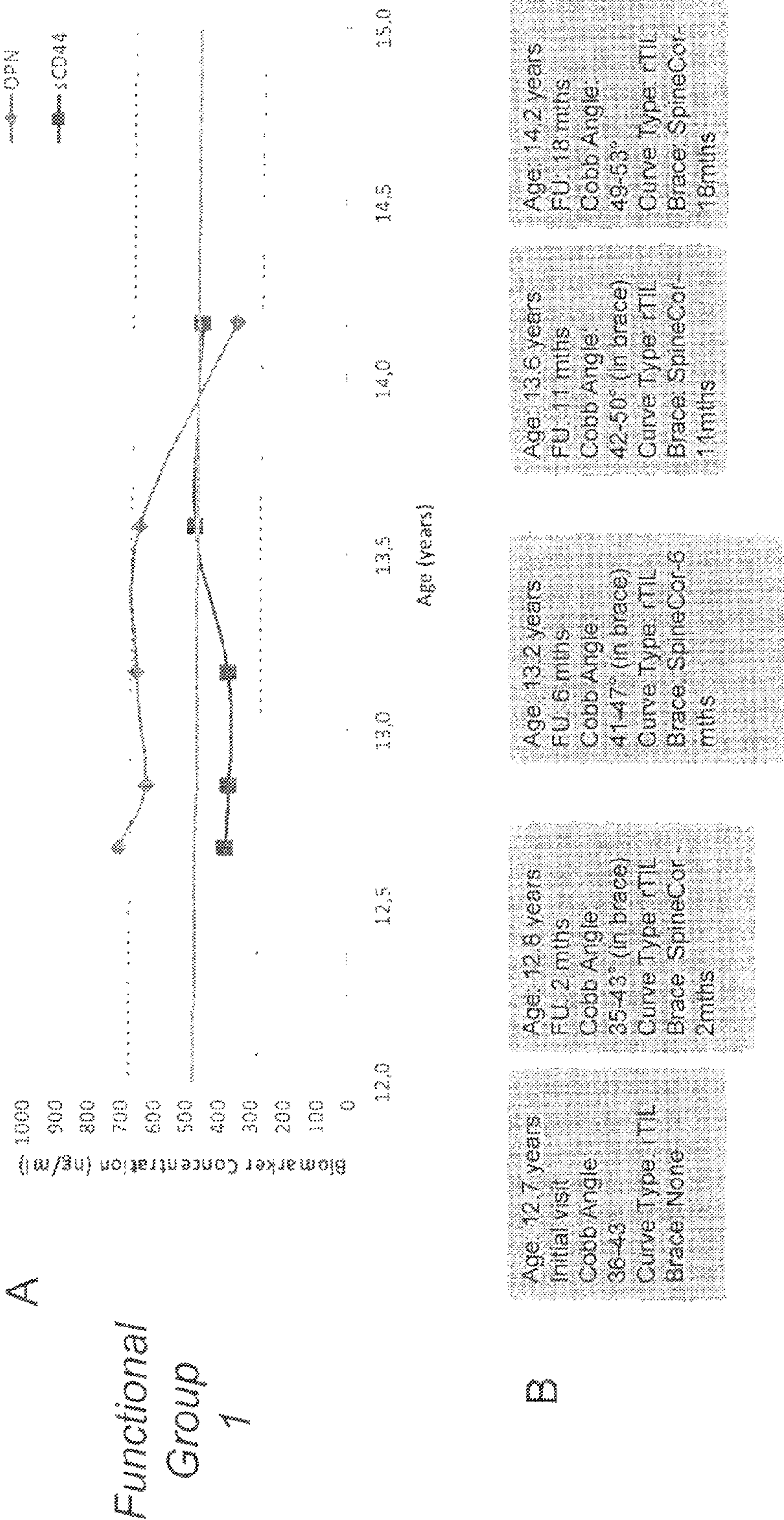
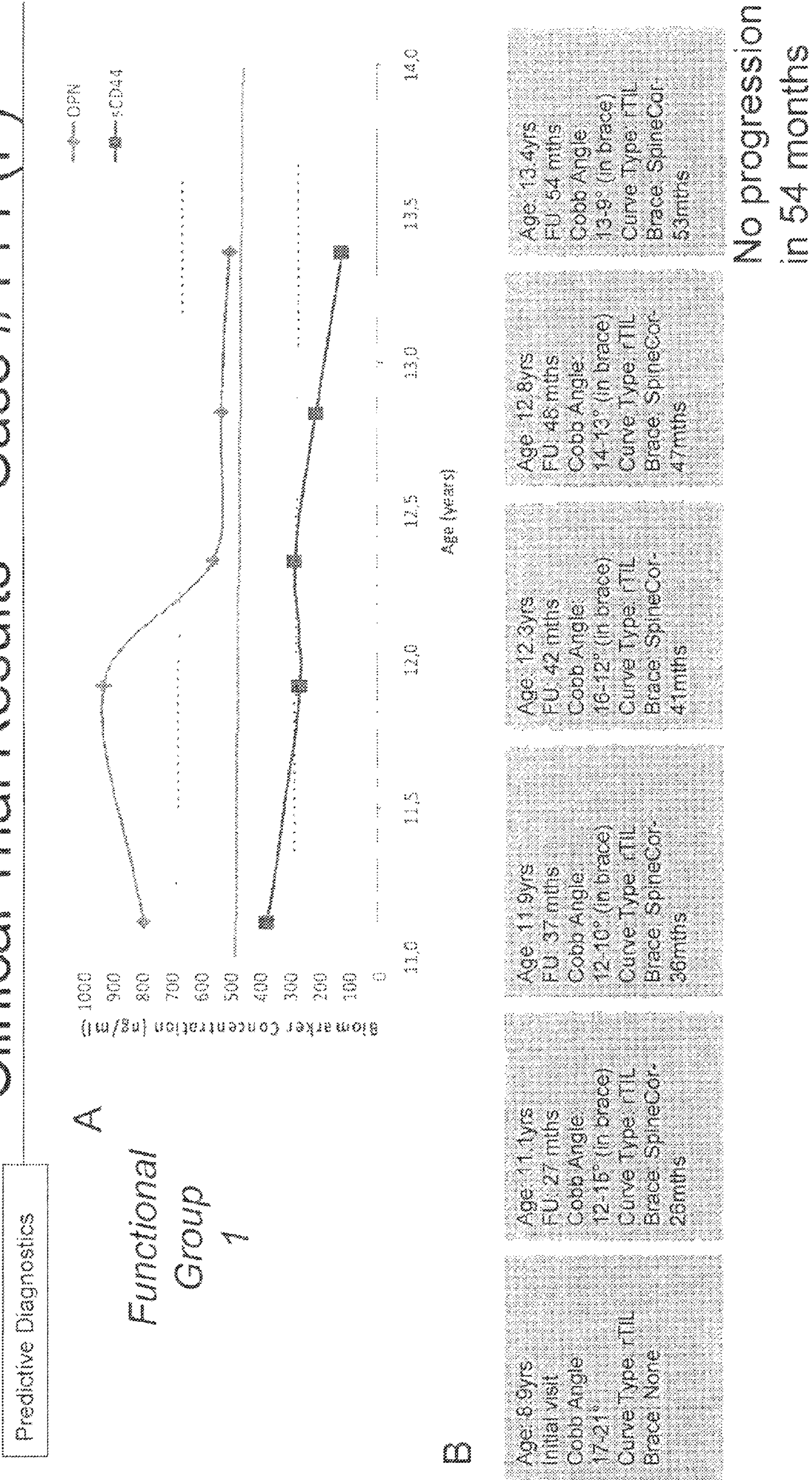


Figure 14

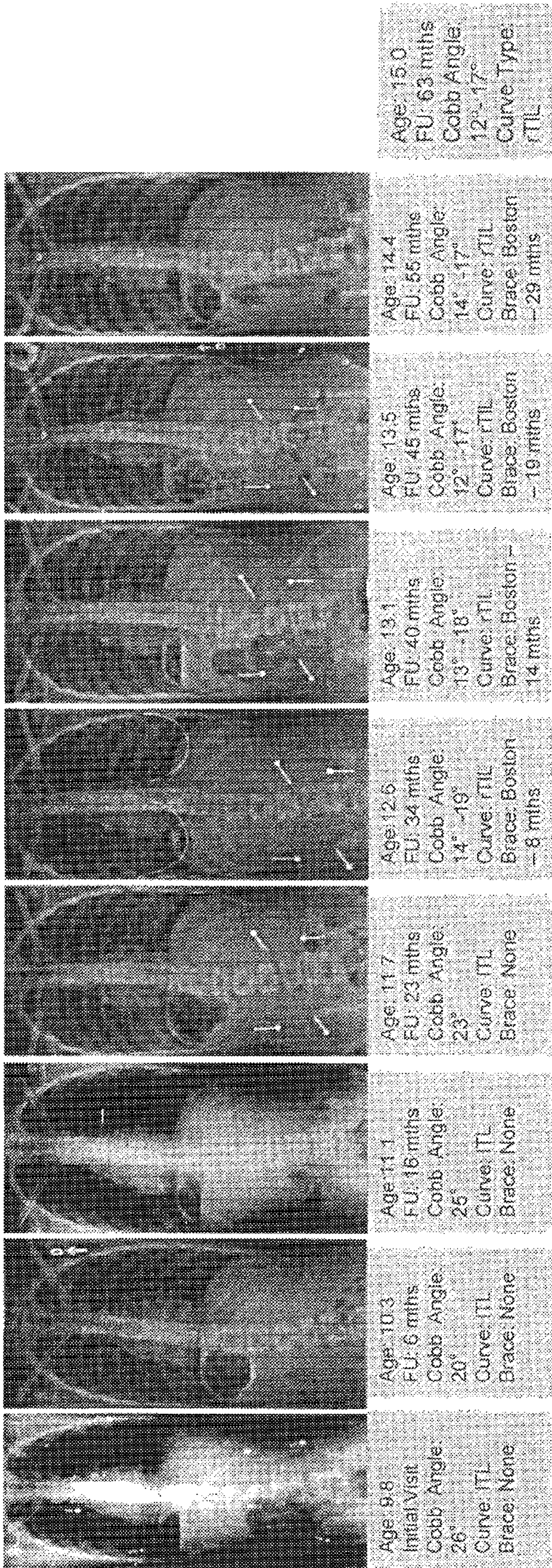
Clinical Trial Results – Case #144 (F)



Predictive Diagnostics

Clinical Trial Results – Case #208 (F)

A



B

FG2

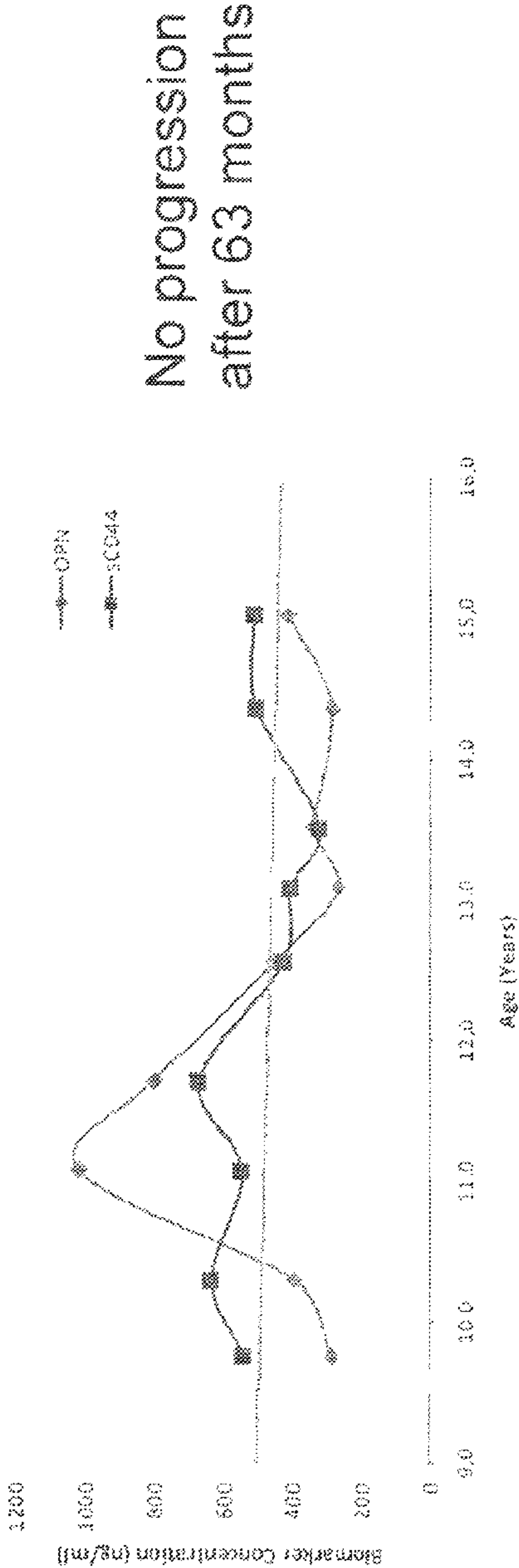
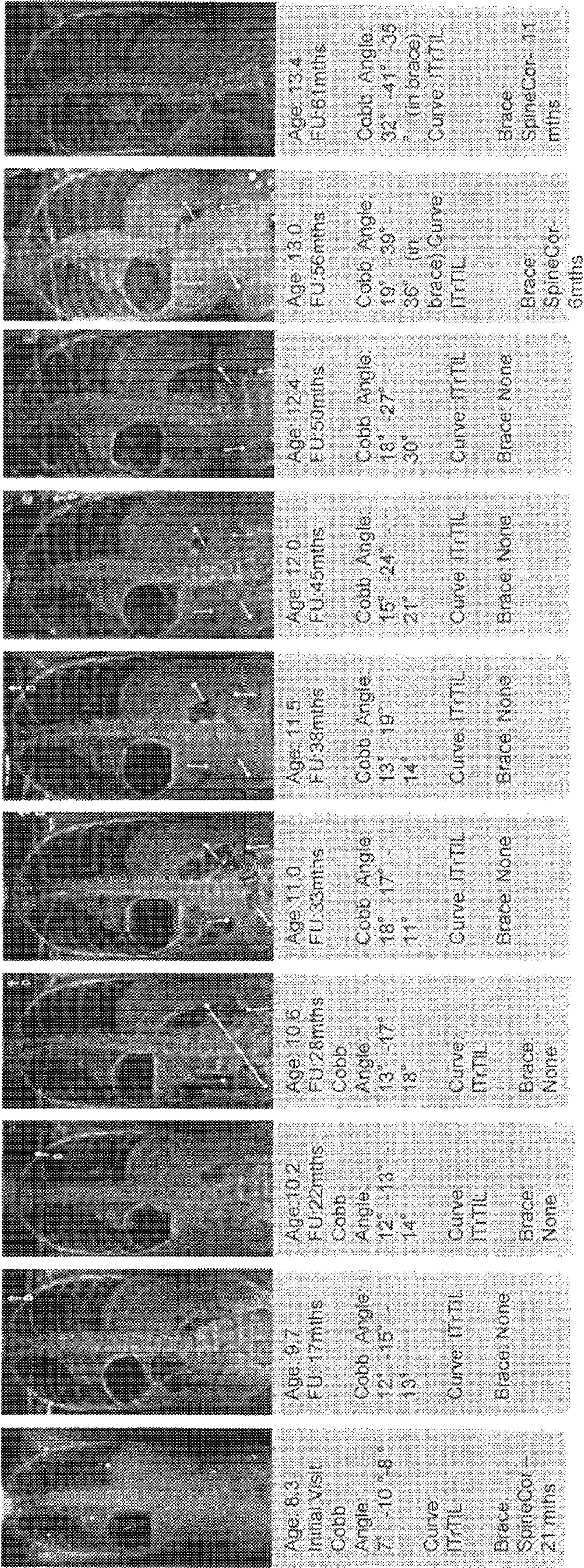


Figure 16

Clinical Trial Results – Case #159 (F)

Predictive Diagnostics

A



FG2

B

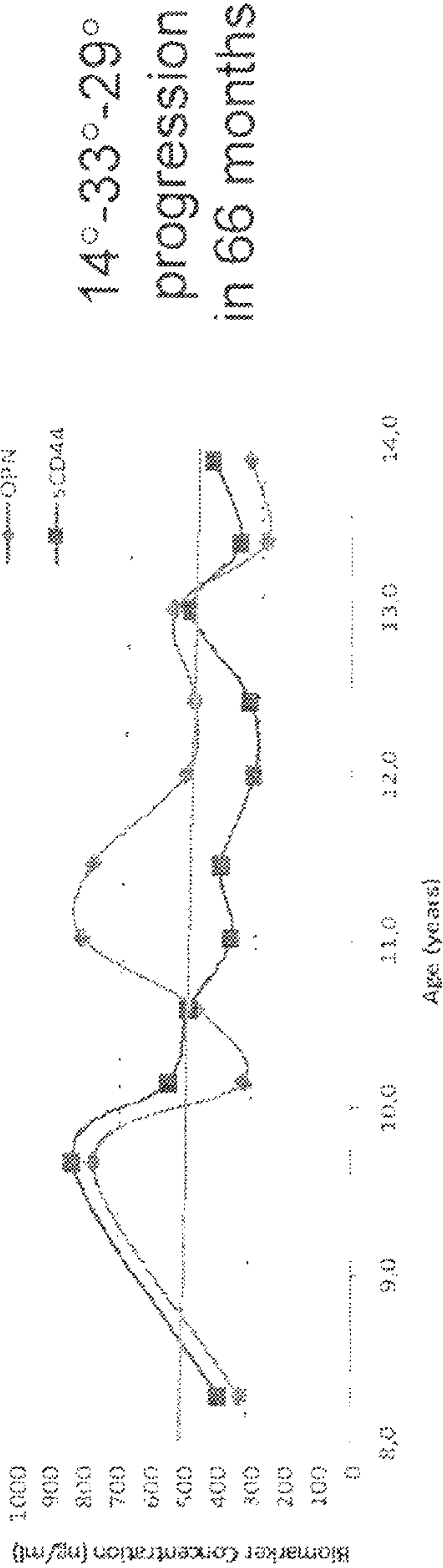


Figure 17

Clinical Trial Results – Case #272 (F)

Predictive Diagnostics

A

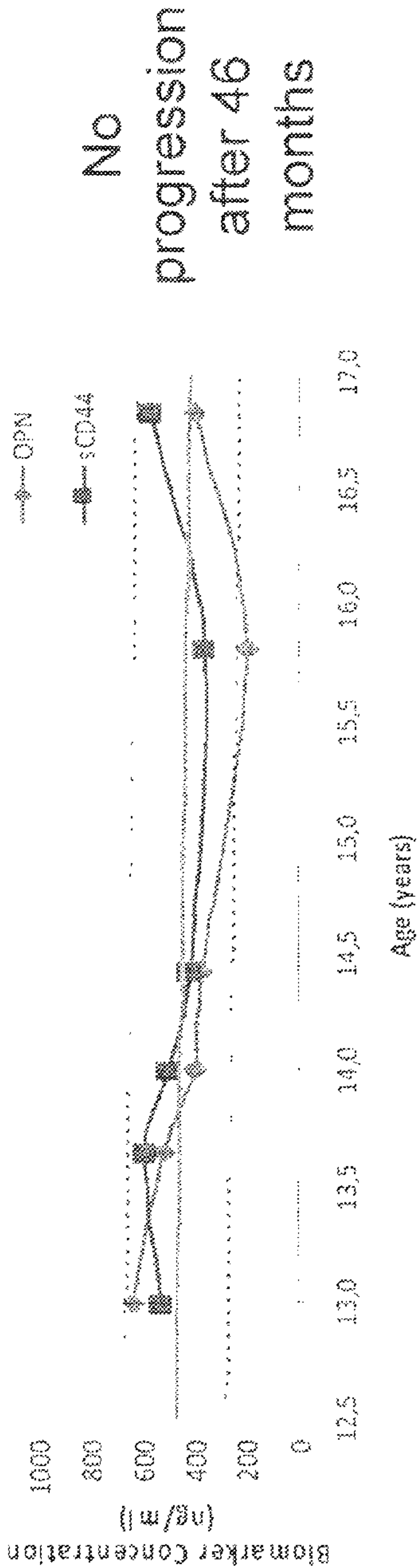
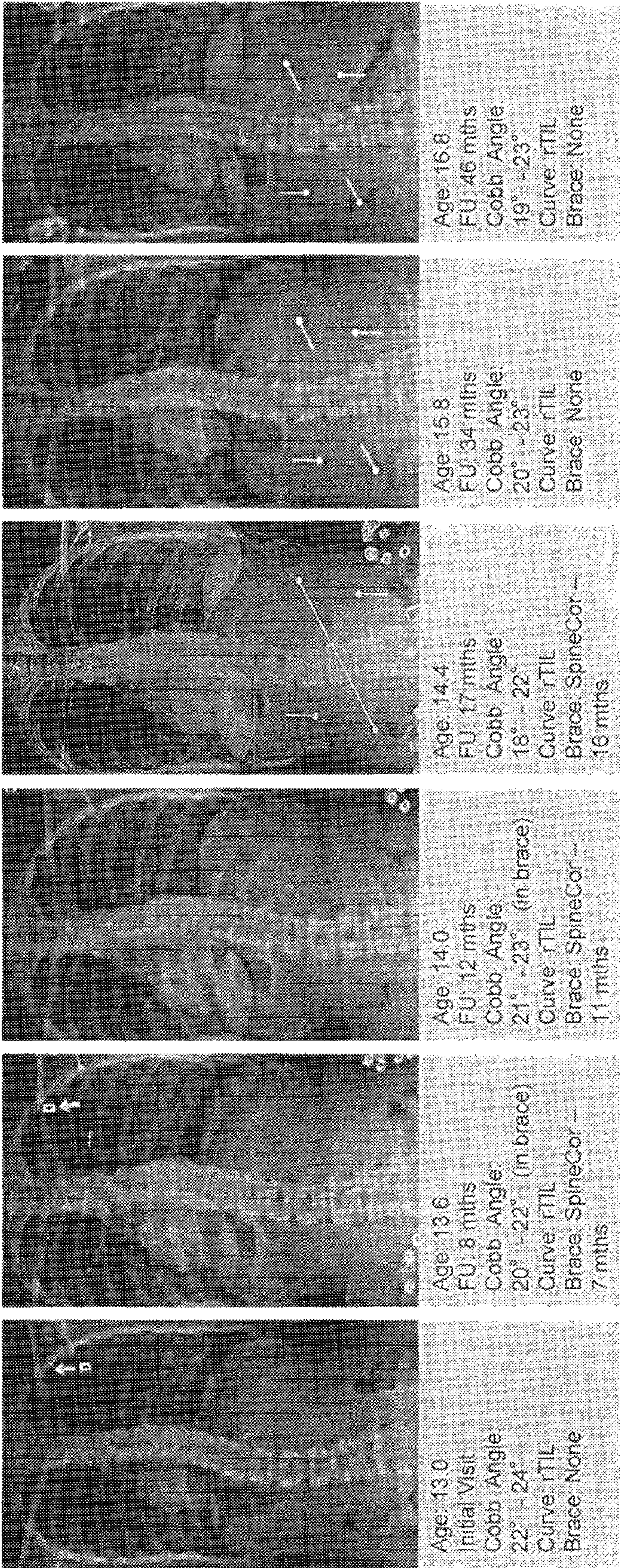
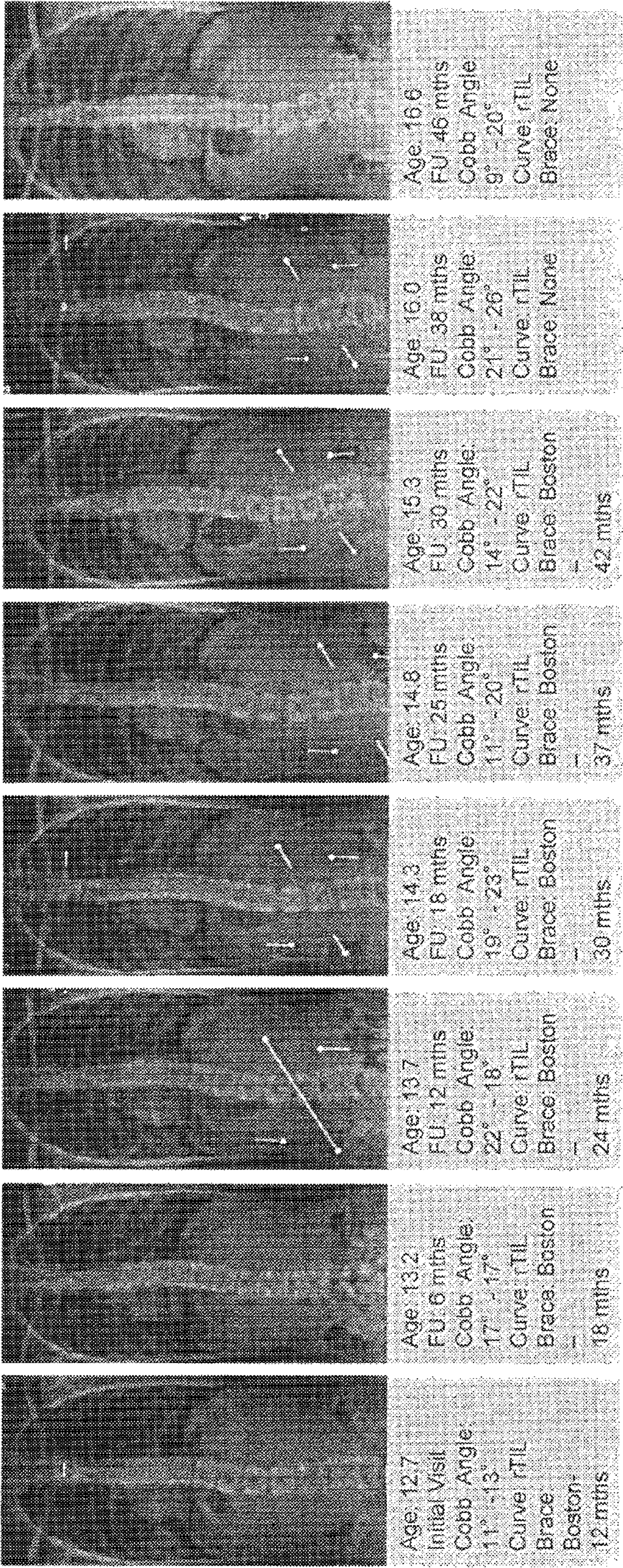


Figure 18

Clinical Trial Results – Case #301 (F)

Predictive Diagnostics

A



B

FG3

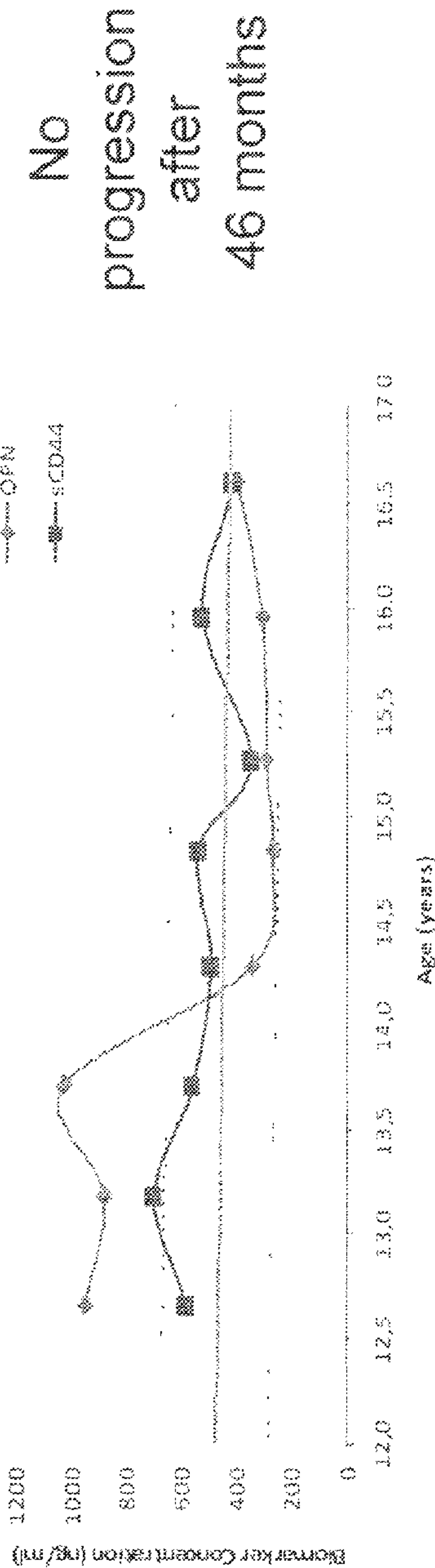


Figure 19

Cell response to OPN is genetically programmed in AIS Patients

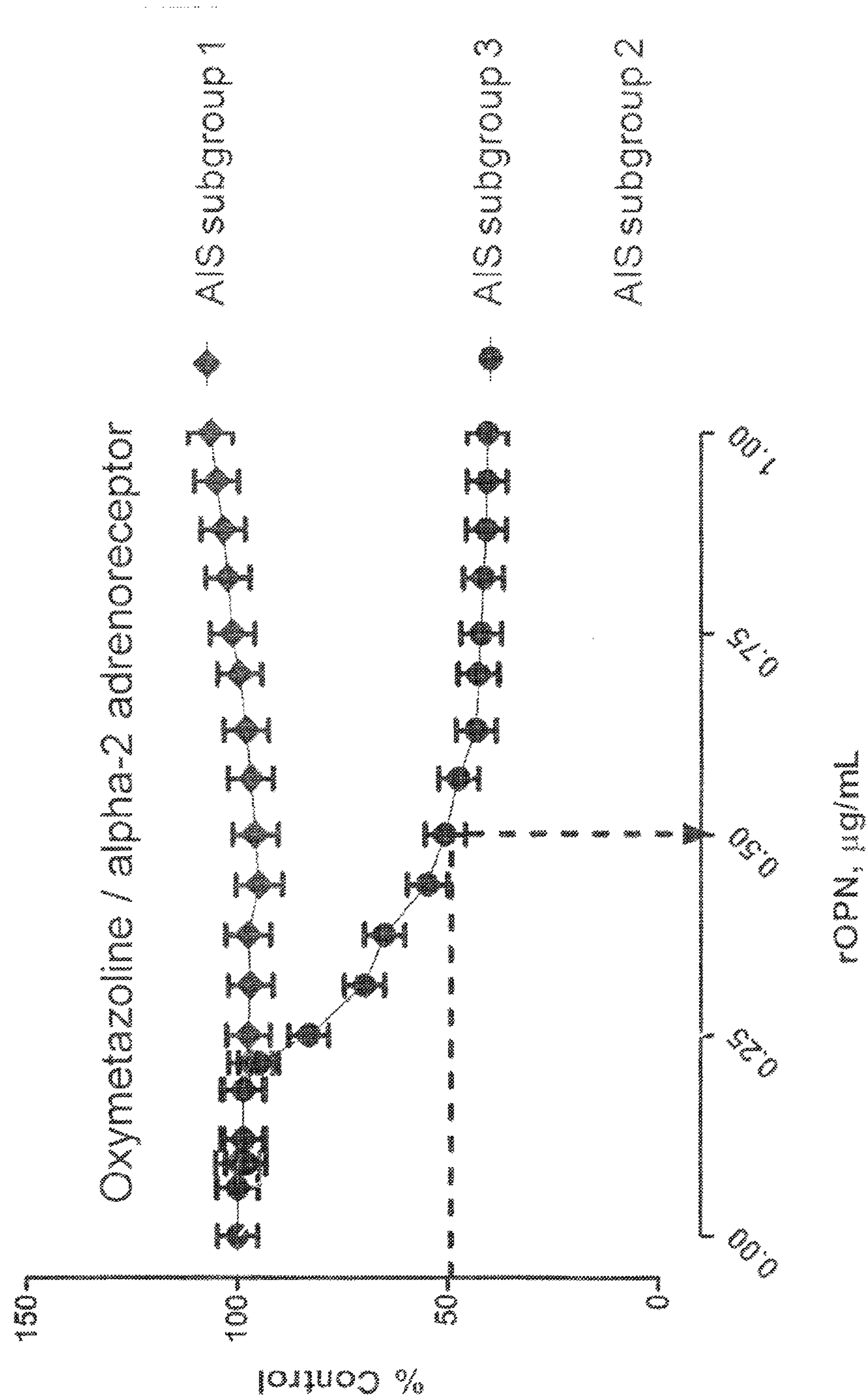


Figure 20

Knockdown of OPN rescued Gi protein mediated signal transduction in ALS

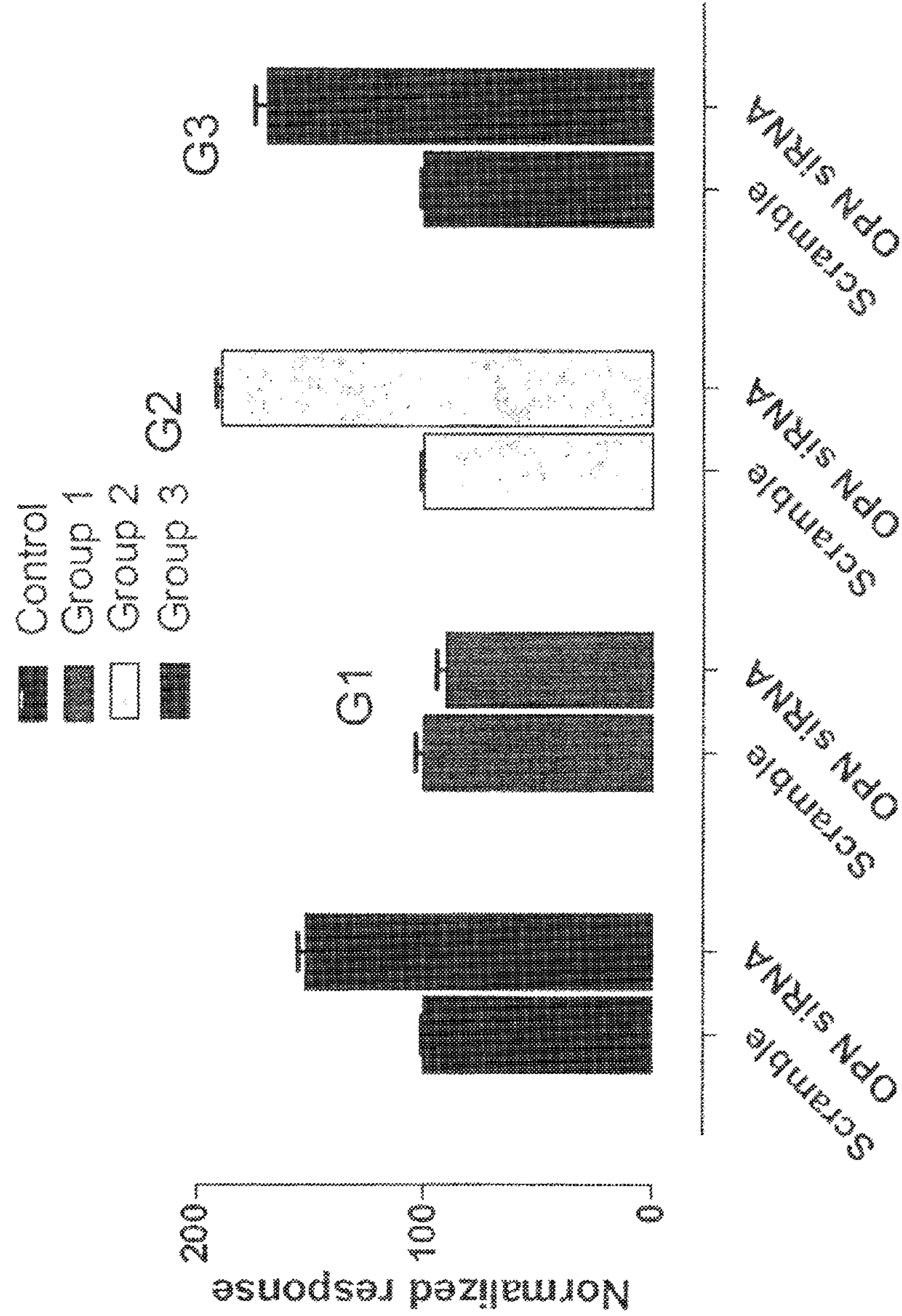


Figure 21

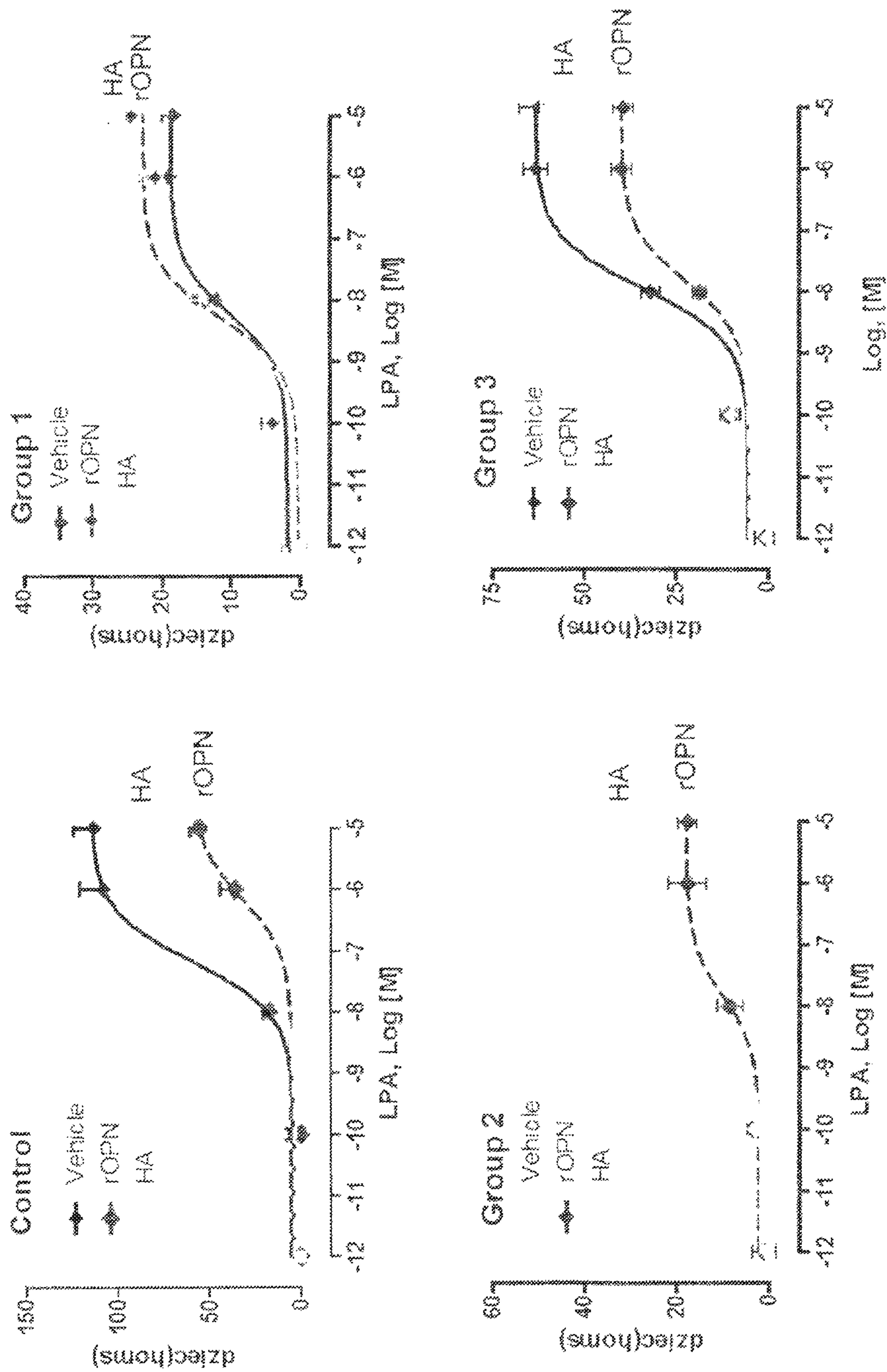


Figure 22

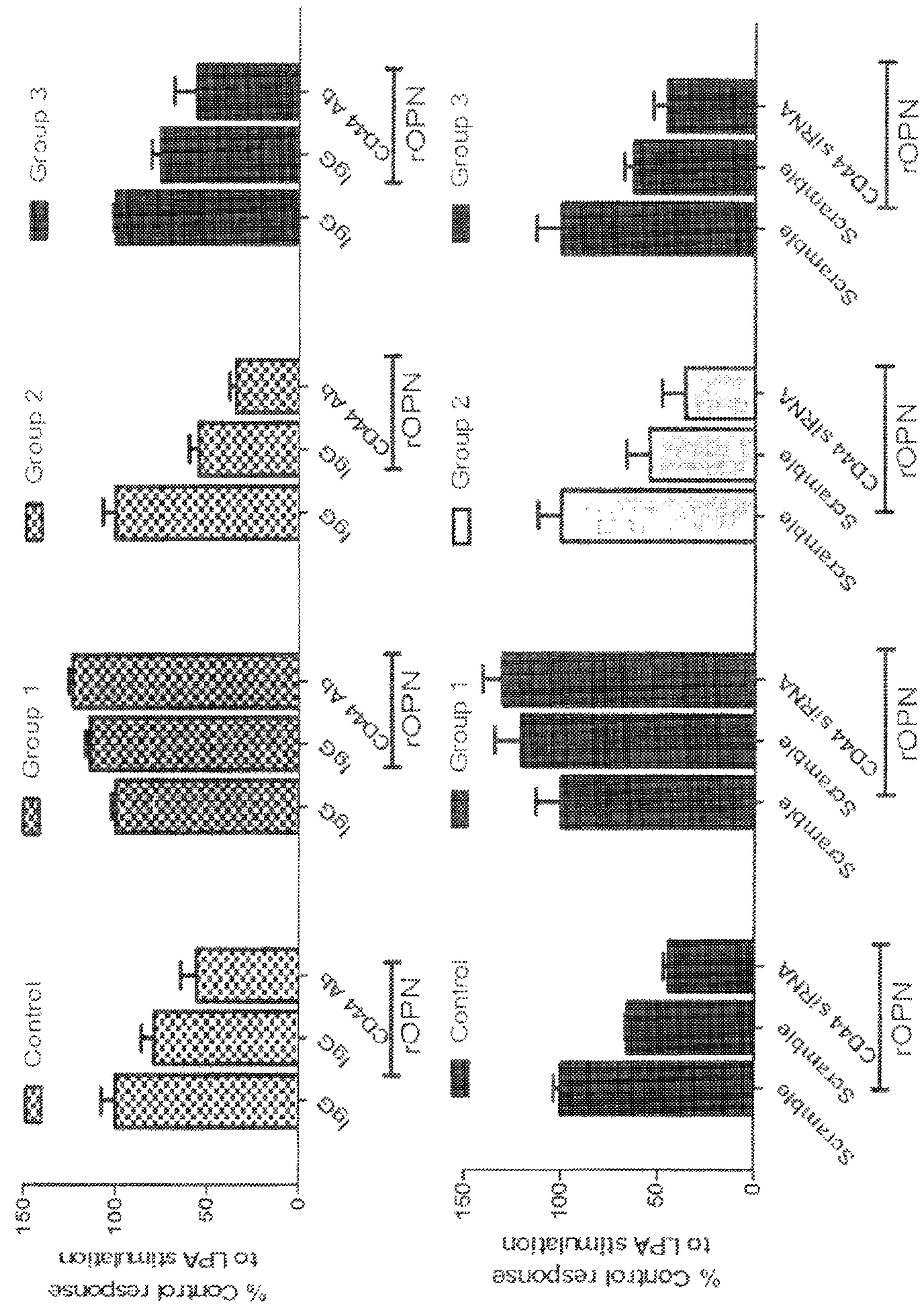


Figure 23

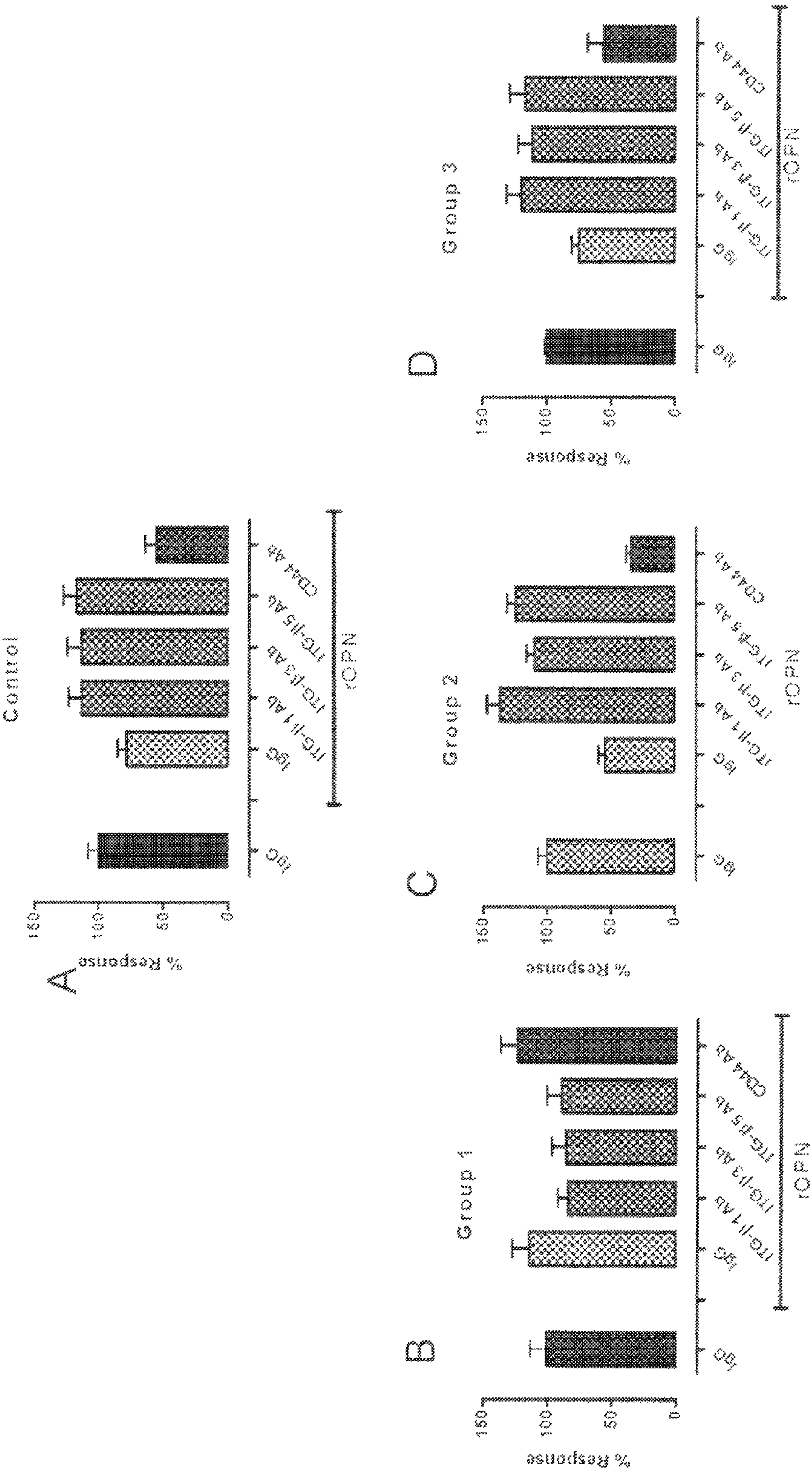


Figure 24

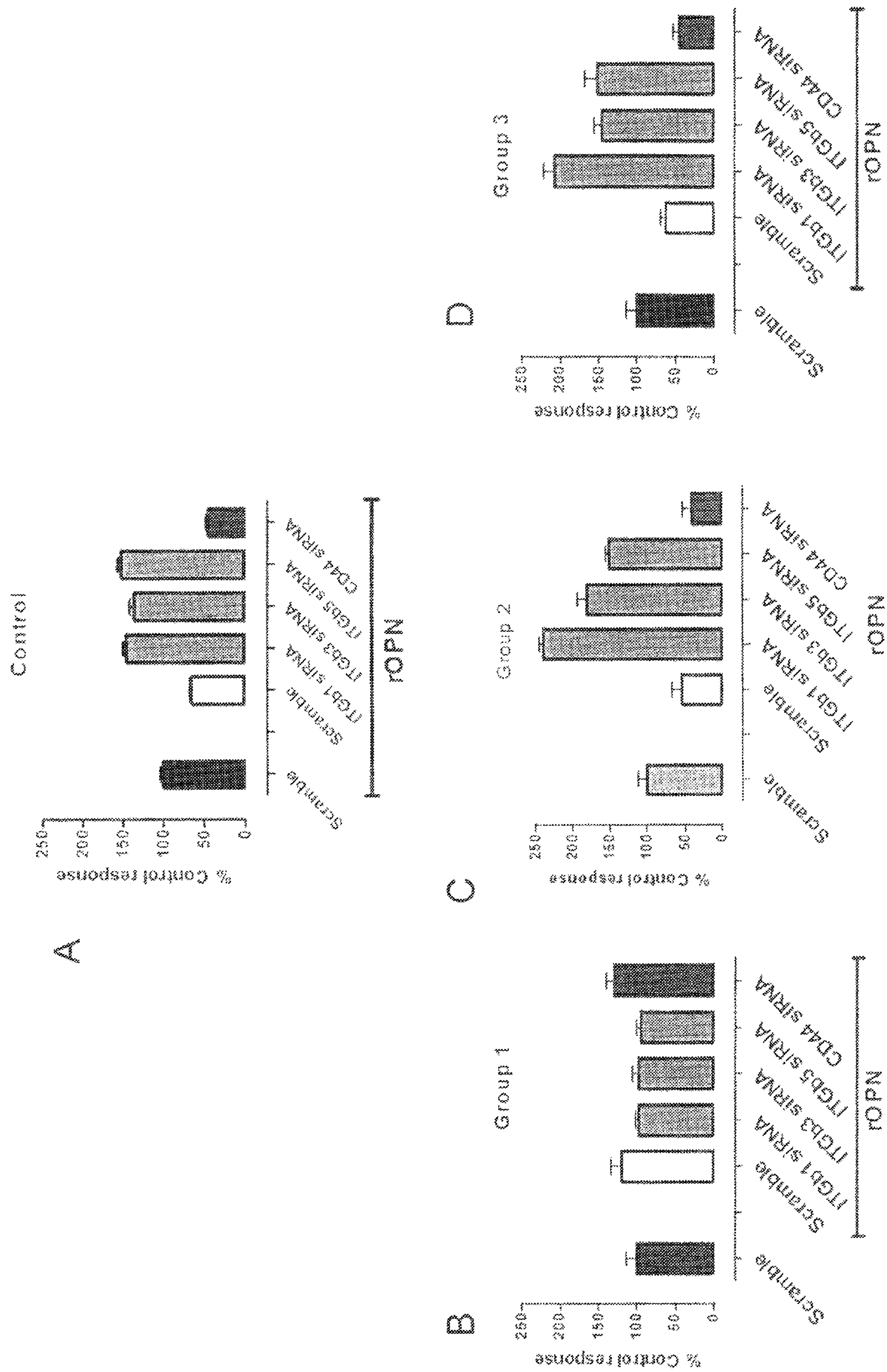


Figure 25

FIGURE 1

Functional group	Effect of OPN	Initial Circulating [OPN]	Brace treatment	Other treatment options (See also Figure 1B)
FG1	Protective	high	No	Increase OPN level or activity (e.g., OPN, OPN agonist. Treatment and preventive measures which increase OPN levels)
		low	Generally, no	Increase OPN level or activity (e.g., OPN, OPN agonist. Treatment and preventive measures which increase OPN levels)
FG2	Risk factor	high	Yes	Decrease OPN level or activity (e.g., OPN antagonist. Treatment and preventive measures which decrease OPN levels)
		low	Yes,	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels)
FG3	Risk factor	high	Yes	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels)
		low	Yes	Decrease OPN level or activity (e.g., OPN antagonist, treatment and preventive measures which decrease OPN levels)