

1 **Title: Advancing modern equine medicine using gene therapy**

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14 Currently, regenerative medicine is seen as a promising alternative to traditional therapies.
15 Tapping into the natural ability of the body to self-restore and heal opens up great potential to treat
16 many disorders, including those which were considered untreatable or for which current approaches
17 do not result in adequate or timely recovery. Stem cells are often considered a "magic bullet" to boost
18 natural regenerative potential. Indeed, these cells are capable of self renewal, thus forming a
19 practically unlimited pool of "spare parts", turning into almost any type of adult somatic cells,
20 replacing dying aged cells or healing injuries. Isolated and (if necessary) expanded *in vitro* or *ex vivo*
21 these cells find more therapeutic applications. Importantly, recent advances in biomedicine suggests
22 that the main therapeutic effects of such stem cell transplantation is not dependent on cell
23 replacement, but rather on paracrine stimulation of regenerative potential of resident cells through
24 cell to cell signaling, consisting of direct contact, soluble protein factors, metabolites and
25 microvesicles. So instead of using stem cell transplantation scientists and clinicians are considering
26 other biologically active substances, which don't contain live cells but contain, for example, growth

27 factors which these cells would secrete. One such approach which has already found wide spread
28 clinical applications is platelet rich plasma, which contains high concentrations of growth factors,
29 other cytokines or even purified recombinant protein growth factors. However, the main disadvantage
30 of such cell-free approaches is the short half-life of transferred biologically active substances, which
31 are rapidly degraded by body.

32 Gene therapy is a new rapidly evolving therapeutic tool which has the potential to provide
33 continuous stimulation of regeneration. Basically, we are 'hacking' host cell genomes by transferring
34 small sections of new genetic programs in the forms of recombinant DNA or RNA molecules. These
35 nucleic acids (in the forms of either pure (naked) plasmid DNA, nano-sized complexes or viral particles)
36 encode different recombinant genes which are then transcribed and translated by host machinery,
37 resulting in the biosynthesis of therapeutic proteins. Thus, instead of repeated delivery of therapeutic
38 drugs (pharmaceuticals, recombinant proteins, etc.) we teach the organism how to continuously make
39 its own medicine. A brilliantly technological yet natural healing mechanism.

40 Presently most of the attention in regenerative medicine is paid towards treating human
41 diseases. Animals, for the most part, are considered only as models for testing human drugs. Although
42 we do see therapeutic efficiency of such treatments in many animal models, there are often
43 differences in the composition of biopharmaceuticals because of genetic differences between humans
44 and animals. These differences have the potential to limit efficiency of human drugs for treating
45 animal diseases due to incomplete homology. Even more importantly, such drugs could raise
46 immunogenicity issues, potentially having long term immunological problems, development of
47 autoimmunity and decreased efficiency of subsequent treatments, or even negative side-effects
48 including anaphylactic shock. When it comes to autologous (or even allogeneic) transplantation or
49 corresponding animal cell-free products, such as platelet-rich plasma, it is not a problem. But in cases
50 of more advanced therapeutic approaches, such as gene therapy, complete homology might be vital.

51 This is why we are focusing our research on developing gene therapy applications using
52 species specific recombinant genes, which will provide full biological activity and simultaneously have

53 no immunological side effects. We have developed plasmid DNA gene therapy drugs, encoding horse
54 specific genes. For example, plasmid DNA encoding equine vascular endothelial growth factor (VEGF)
55 and fibroblast growth factor 2 (FGF2) [1] which demonstrated safety and efficiency in a recently
56 published case report study of treating tendinitis and desmitis in horses [2]. Treatment of these
57 conditions is a tedious task for veterinary doctors. Existing techniques using autologous or allogeneic
58 stem cells or platelet-rich plasma injections have limited efficiency, thus making development of new
59 strategies for tendon regeneration of great importance. The mechanisms of action of the gene therapy
60 involving VEGF and FGF2 probably involves increased vascularization of damaged tissues, resulting in
61 higher rate of regeneration. Both VEGF and FGF2 are well known growth factors with wide spectrum
62 of mitogenic and angiogenic activity. They also promote regeneration of muscular and connective
63 tissue. More importantly, in combination these growth factors demonstrate synergetic effects, which
64 surpass effect of single growth factor therapy applications.

65 With gene therapy becoming such a viable option, much consideration needs to be given to
66 not only the design and development of new therapies and applications, but also to how animals
67 receive treatment. The need for training for both established veterinary surgeons and undergraduate
68 students is becoming essential. Initially the regimes will be implemented by veterinary gene therapy
69 specialists but over time these therapies will be used in clinics throughout the world. Naturally much
70 care and consideration is also required in ensuring that all new therapies are appropriately tested and
71 have high standards of production and regulation. In addition these treatments will need to be
72 discussed with the international associations involved in the regulation and breeding of horses. As
73 with any new treatment the matter of educating and informing the public, owners, health and welfare
74 providers and veterinary professionals is of utmost importance. With so many types of gene delivery
75 potentially available and so many more being developed and trialed, the intricacies of each treatment
76 for differing conditions can be difficult to portray to the owner. As of December 2017, three human
77 gene therapy drugs had been approved by the United States Food and Drug Administration [3]. With
78 our latest successful trials and the advances in technology and genetics, the future for veterinary gene

79 therapy looks promising and it is likely that many more therapies will become licensed for use in both
80 human and animal medicine.

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84 **Conflicts of interest**

85 The authors declare no conflicts of interest.

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