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Restoration of eye closure in facial paralysis using implantable electromagnetic actuator☆

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Lagophthalmos

Summary The most devastating outcome of facial nerve paralysis is the inability to completely close the eye as it can lead to corneal ulceration and loss of vision. Gravity-assisted eye closure with upper lid loading is commonly used; however it is limited in replicating physiological eye closure to adequately lubricate the cornea. Superior results can be obtained using more advanced reconstructive approaches, however they depend on nerve regrowth which may be unpredictable and prolonged. This report describes a novel technique for creating an active eye closure using an implantable actuator. A generated magnetic field creates lateral movement in an electromagnet that is translated to the eyelid through a sling design. The device is powered wirelessly through a transcutaneous induction link and can be hermetically encapsulated for patient safety. The initial phase of device development is presented including data of a fully functioning prototype and the results of its application in animal and human cadavers.

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Introduction

Facial nerve paralysis (FNP) results in significant morbidity through loss of function of facial muscles that provide ocular protection, nasal airflow, facial expression, and oral continence. Bell's palsy is the most common cause of FNP, which is usually a self-limiting condition. Other causes include neoplastic and traumatic facial nerve injuries where normal nerve function may be permanently lost. The most feared consequence of FNP is the inability to completely close the eye as the secondary corneal dryness can result in corneal ulceration and eventual blindness.[1]

The eyelid serves a complex function in lubricating the cornea through its unique muscle fibre arrangement and movement around the globe, making it exceptionally challenging to reanimate.[2] Lateral tarsorrhaphy and upper lid loading introduced over 60 years ago remain the most commonly used methods to assist eye closure in FNP.[3] Lid loading is simple, safe and reversible but ineffective in restoring normal lid function as it is posture dependent, slow, asynchronous and incomplete during spontaneous blink. Its success is dependent on choosing the correct weight and placing the weight in the right position in order to achieve optimal force vectors for closure in the upright position.[3,4] A variety of reconstructive approaches have been used to achieve effective eye closure, including the palpebral spring,[5] nerve grafts (ipsilateral and cross facial),[6,7] temporalis muscle transfer[8] and neurotised free

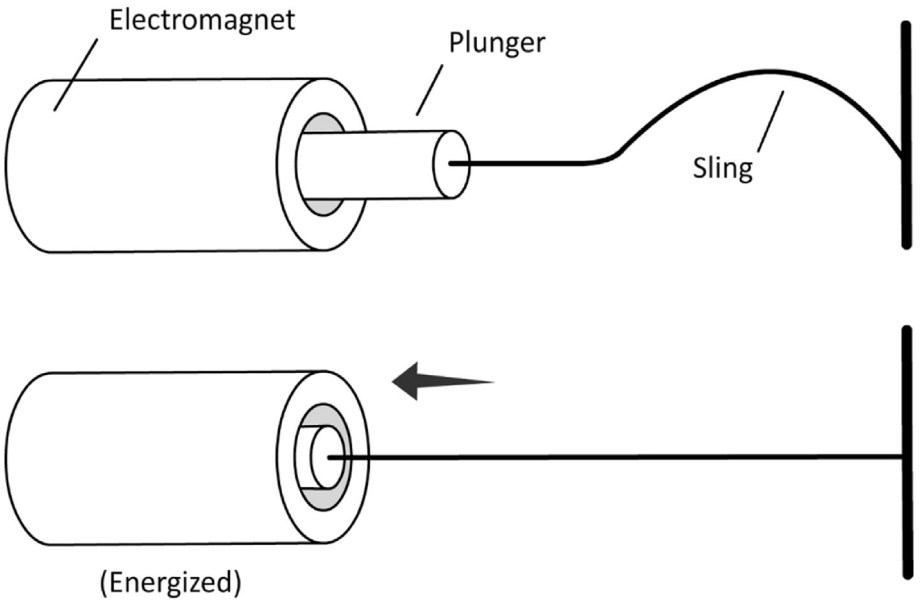

Figure 1 Solenoid action on the sling to close the eye. The starting position of the plunger inside the solenoid is shown (top). Once the solenoid is energized the plunger retracts (bottom), pulling the sling to close the eye.

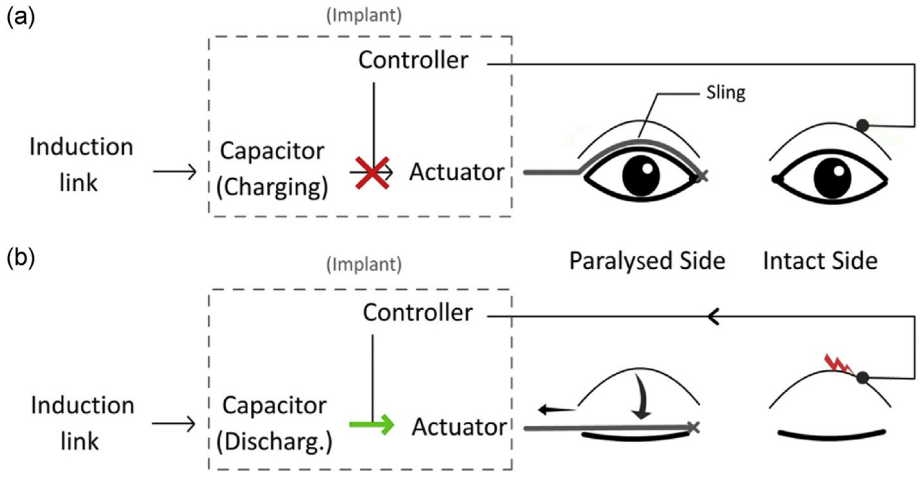

Figure 2 Schematic of device operation. During non-blink state (a) power is continuously transferred across the induction link to charge the capacitor without energizing the actuator. A sensing mechanism detects contralateral (intact) eyelid closure, which feedbacks to a controller circuit to trigger capacitor discharge into the actuator (b). The energized actuator tensions the sling to close the (paralysed) eyelid.