On tendon transfer surgery of the upper extremity in cerebral palsy
Kreulen, M.

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ics and of motor development of the maturing musculoskeletal system forms the basis of the current diagnostic algorithms and treatment regimes.

Surgery of the upper extremity in cerebral palsy is classically aimed at improvement of the range of motion of the affected joints and, if present, at the correction of joint instability. Today, a variety of procedures is available to compose the surgical plan for the correction of muscle imbalance, considering the needs of each individual patient. Tendon transfer and tendon rerouting procedures are in particular employed to balance the forces that cross a joint. Despite the progress in understanding cerebral palsy, however, knowledge of the biomechanics of tendon transfer and of the affected kinematics of the upper limb in cerebral palsy is lacking, while it is indispensable for appropriate surgical planning to meet the requirements of an optimal muscle balance.

This thesis

From this perspective, we have embarked on a research project that aims at the ultimate goal to compose an optimal combination of surgical procedures tailored to balance the forces in the upper extremity as required by the desired functional improvement of the patient. This thesis presents the results of the first step in this
process, which is to test the validity of the current biomechanical concept of tendon transfer. According to this concept, the original function of the selected donor muscle is completely eliminated by disconnecting the tendon from its insertion. Subsequently, it is assumed that the unchanged biomechanical properties of this muscle can be made available on a new location by transfer of its tendon, provided that the architecture of the muscle is not damaged and the appropriate muscle length after transfer is achieved. Furthermore, the new function of the transferred muscle is presumed to only affect movements around the rotation axes that it crosses. Vice versa, all postoperative change of these movements is attributed only to the transferred muscle function. The correction of muscle imbalance across other joints should be addressed by additional procedures. The research presented in this thesis challenges all these assumptions on the hypothesis that the classical biomechanical concept of tendon transfer is incorrect.

Outline

A prerequisite for the classical concept is that the biomechanical properties of a muscle do not change when its anatomical environment changes. The observations presented in the first two chapters of this thesis investigate the possibility that flexor carpi ulnaris muscle function is related to the surrounding fascial connective tissue. If so, both the preservation of the muscle's anatomical environment in tenotomy (Chapter one) and its dissection during tendon transfer (Chapter two) will affect the muscle's function differently than expected according to the classical concept.

Subsequently, upper limb kinematics are studied to assess the functional result of tendon transfer. A three-dimensional video analysis system was set up for this purpose. The selection and design of tendon transfer to correct a pronation deformity was questioned by a prospective clinical outcome study using this three-dimensional video analysis system (Chapter three) and, subsequently, by using a computer simulation of the transfer procedure on a three-dimensional biomechanical model of the arm (Chapter four). It is nearly impossible to obtain direct proof that the observed change in forearm rotation is caused directly and only by the function of the transferred muscle. However, the mechanical evaluation of the computer simulated tendon transfer should at least have been compatible to the results of the clinical outcome study. If not, alternate forces or pathways should be entertained and possibly integrated in the tendon transfer concept.

Finally, the movement patterns of the entire extremity and trunk were studied using the 3D video analysis system. For this, a completely new parameter called 'extrinsic forearm rotation' was introduced to study movements outside the forearm that supplement forearm rotation (Chapter five). The presence of pathological
movements directly associated with impaired forearm rotation was studied by comparison of this new parameter between ten patients with cerebral palsy and ten case-matched controls. The effect of surgical correction of the pronation deformity on these associated movement patterns was studied one year postoperatively in these patients (Chapter six). The degrees of freedom that are aimed to improve by surgery may not be the only degrees of freedom that are affected. If so, such an effect should be anticipated in surgical planning as it may involve deformities that are affected by the correction of others.

This thesis is concluded with an epilogue in which I discuss how the results of the presented research may dispute the aforementioned classical concept of tendon transfer, and how this may affect surgical treatment of the upper extremity in cerebral palsy in the future.

"... The loss of a lower extremity is a great privation, but experience shows that the deprivation of the use of the arm and hand is felt as a far greater affliction; so much the greater therefore must be the reward of him who, by adding to the common stock of knowledge on the remedy of this, can so largely contribute to the welfare of his fellow creatures."

WJ Little, 1843 42