ISB 2013 BRAZIL
XXIV CONGRESS OF THE INTERNATIONAL SOCIETY OF BIOMECHANICS
XV BRAZILIAN CONGRESS OF BIOMECHANICS

BIOMECHANICAL CONSEQUENCES OF EXTENSOR INDICIS PROPIUS TRANSFER AFTER IRREPARABLE EXTENSOR POLLICIS LONGUS TEAR

[1,2]Guilherme Auler Brodt, Max William Rusch, [3]Giovanni Ferreira, [1]Lucas Boeira and [1]Jefferson Fagundes Loss
[1]Universidade Federal do Rio Grande do Sul;
[2]Universidade de Caxias do Sul;
[3]Universidade Federal de Ciências da Saúde de Porto Alegre;
e-mail: guilhermebrodt@gmail.com, web: www.ufrgs.br/biomec

SUMMARY
Knowing the biomechanical consequences of tendon transfers is important before the chosen of the muscle used at the transfer. After irreparable extensor pollicis longus tear it is common to use the extensor indicis propius in the transfer. However little is known about the consequences of this transfer. In this study we simulate the surgery and concluded that the gains are greater than the losses after this procedure.

INTRODUCTION
The Extensor Pollicis Longus (EPL) tendon rupture is a rare injury, although it comprises several etiological factors [1]. In literature are described for this occurrence factors like: rheumatoid arthritis [2]; osteoarthritis [3]; corticosteroids usage [3]; repetitive effort tenosynovitis [4]; crush injuries [5]. Besides, EPL rupture pathogenesis isn't entirely known and could be related to mechanical factors [6].
Patients with EPL tendon rupture states pain and, through physical examination, demonstrate inability at thumb interphalangeal joint extension and reduced force at metacarpophalangeal joint [3,7].Also can be observed reduced force production capability at wrist extension [4].
The surgical procedure choice is determined by the time interval between the rupture and the diagnosis. In cases which this interval leads to loss of tendon length over the region of the rupture, shortening and atrophic changes in the muscle, it makes the use of original muscle as the motor unacceptable, the option is tendon transfer. The Extensor Indicis Proprius tendon transfer (EIP) in EPL rupture cases, in addition to being the most popular [1], furthermore is the most documented in the literature [2,3,4,5,6,8,9]. Besides, EIP is the most versatile muscle for hand tendon transfer surgeries [8]. However, the mechanical consequences related to this procedure, such as alterations in the force production capability, moment and moment arm of transferred tendons, have not been well described yet.
Biomechanical models have often been used to simulate surgical procedures in order to obtain mechanical and physiological information about the clinical outcomes [10]. These simulations have been applied to the study of muscle reinsertions as well as tendon transfer of the upper limb [10]. These surgical simulations are important predictive of surgical procedure success under the mechanical point of view.
Thus, the objective of this study was to analyze the biomechanical implications, to thumb and index finger, of the EIP tendon transfer to EPL's insertion site, using a upper limb three-dimensional simulation model.

METHODS
The model used in this study is an open- source three-dimensional computational model of the upper extremity with 50 Hill-type muscles compartments that represent very well the mechanics of these muscles [11]. The complete EPL rupture was considered for this study. In this situation the muscle loses all the force production and moment generation capacity at every joint which it crosses. In the used model the total moments and muscle forces are calculated as the sum of each muscle individual contribution [11]. The EIP muscle path was changed at the level of carpus, simulating a transfer surgical procedure of the EIP muscle to the EPL path, in agreement with the surgical technique suggested by authors [7,8]. The muscle-tendon paths of the EIP were altered interactively using OpenSim 2.0 [12]. In order to avoid any inconsistent outcomes related to these limitations, we were careful to maintain the specific characteristics of the EIP (such as fiber length, pennation angle, and force-length curve shape).
The considered muscles were the following: Extensor pollicis longus (EPL), Extensor pollicis brevis (EPB), Abductor pollicis longus (APL), Flexor pollicis longus (FPL), Extensor digitorum communis (EDC), and Extensor indicis propius (EIP). The transfer biomechanical implications for comparison of pre-rupture, post-rupture and post-transfer were: moment and moment arm for thumb carpometacarpal (TCM), thumb metacarpophalangeal (TMP) and index finger metacarpophalangeal (IMP).

RESULTS AND DISCUSSION
The resulting moments and moment arms for each joint analyzed can be observed in Figure 1. Prior to rupture the moment peak at TMP joint was 0.47 Nm, and after rupture it was 0.13 Nm, being reduced by 73%. The post-transfer

moment peak was 0.33 Nm. At TCM joint the moment peak was 1.30 Nm for the healthy muscle simulation, in the post-rupture the moment peak was 1.01 Nm, and later in the post-transfer situation the moment peak reaches 1.18 Nm. At the IMP joint the moment peak decrease from 0.37 N.m pre-surgery to 0.17 N.m at post-surgery a decrease of 54% due to transfer of EIP.

The knowledge of moment and moment arm behavior and the influence of force and moment arm on the produced moment can be of great use to the clinic making decision in the surgical procedure. It is well known that full EPL's tear compromises thumb function especially in activities of dayly living like grasping eating utensils and writing instruments [1,7,13]. The EPL muscle is essential to stabilizing the joint of the thumb, especially during in unstable tasks [14]. Moreover, the EPL participates as an agonist or synergist for all movements of the thumb [15].

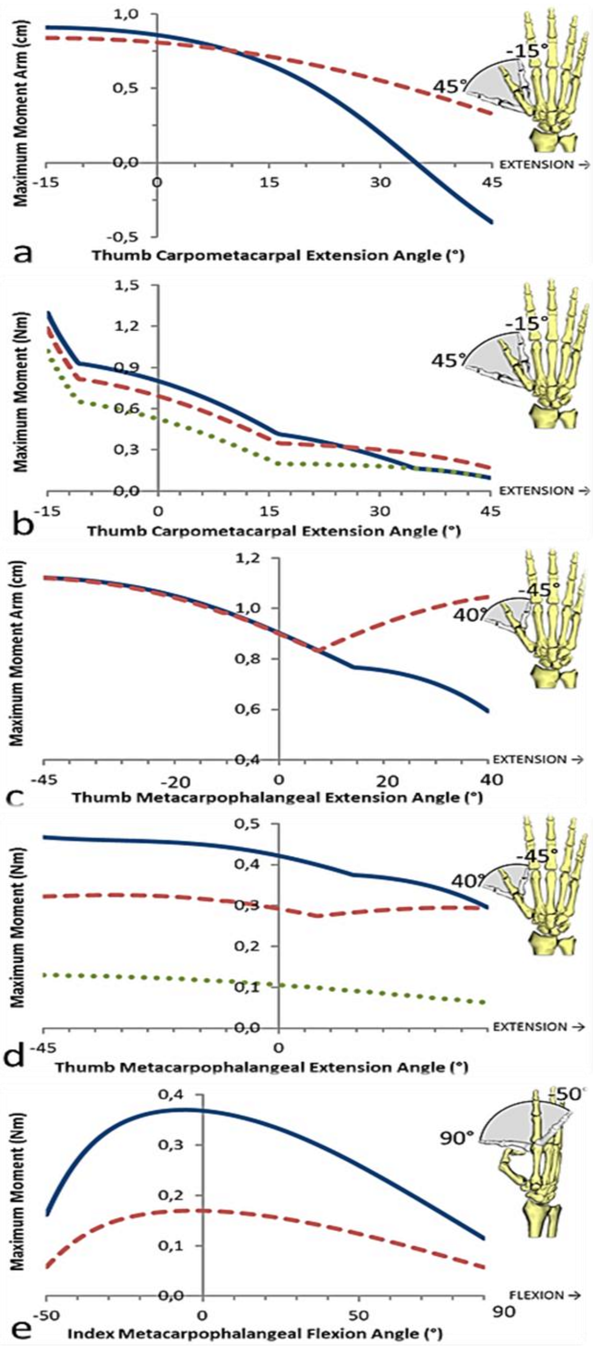

Figure 1: Thumb carpometacarpal moment (a) and moment arm (b), thumb metacarpophalangeal moment (c) and moment arm (d) and index finger metacarpophalangeal moment (e) capacities under pre-rupture (continued lines), post rupture (dotted lines) and post- tendon transfer surgery (dashed lines) conditions.

Tendon transfer procedures have remained more of an art compared to other areas of medicine [13]. The knowledge of moment and moment arm behavior and the influence of force and moment arm on the produced moment can be of great use to the clinic decision making at surgical procedures. It is well known that full EPL's tear compromises thumb function especially in activities of dayly living like grasping eating utensils and writing instruments [1,7,14]. The EPL muscle is essential to stabilizing the joint of the thumb, especially during in unstable tasks [14]. Moreover, the EPL participates as an agonist or synergist for all movements of the thumb [15].

In this study, both thumb joints decreased in moment-generating capacity, which shows the multiarticular role of this muscle. We found that, after tendon transfer, much of the muscle functions were recovered and the transferred EIP tendon moment arm were very close the EPL before the surgery. At TMP joint 70% of the maximal moment capacity was recovered and at TCM joint 91% of the maximal moment capacity was recovered after the tendon transfer compared with the healthy. The cost-benefit ratio is good in this situation, once the EIP is just an assessor at the IMP extension. We must point that this is a simulation study and factors as neural control and muscle activation were not taken into consideration once after a tendon transfer the patient need to relearn how to use his or her joint functions.

CONCLUSIONS

The EIP transfer to restore APL function is a good decision to surgeons during clinic decision making, because the loss of function in the Index finger is smaller the function gains in thumbs joints.

ACKNOWLEDGEMENTS

We wish to thank ISB support, CAPES and CNPQ for the help with resources and equipment.

REFERENCES

1. De Smet, L, et al. *Acta Orthop Belg*, 63:178-81, 1997.
2. Ozalp, T, et al. *Acta Orthop Traumato*, 41:48-52, 2007.
3. Lloyd, TW, *Br J Sports Med*, 32:178-9, 1998.
4. Fujita, N, et al. *Knee Surg Sport Tr A*, 13:489-91, 2005.
5. Durmuş, D, et al. *Turk Fiz Tip Rehab D*, 55:36-8, 2009.
6. Ansede, G, et al. *Skeletal Radiol*, 38:81-84, 2009.
7. Fernandes, C, et al. *Rev Bras Ortop*, 36:336-9, 2001.
8. Noorda, P, et al. *J Hand Surg*, 19:844-9, 1994.
9. Hung, Y, et al. *Arch Orthop Trauma Surg*, 125:281-4, 2005.
10. Mogk, M, et al. *J Biomech*, 44:669-75, 2011.
11. Holzbaur, S, et al. *Ann Biomed Eng*, 33:829-40, 2005.
12. Delp, S, et al. *IEEE t bio-med eng*, 54:1940-50, 2007.
13. Lieber L, et al. *Muscle Nerve*, 23:1647-66, 2000.
14. Johanson, E, et al. *J Hand Surg*, 26:698-705, 2001.
15. Kaufman, R, et al. *Clin Biom*, 14:141-150, 1999