

Theses of a doctoral (PhD) dissertation

**CLINICAL AND BIOMECHANICAL STUDIES OF CTTA TECHNIQUE
IN DOGS**

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The history and the objective of the doctoral dissertation

Cranial cruciate ligament rupture in the stifle joint is the most common cause of hindlimb lameness in dogs. The treatment of this condition is one of the most discussed topics in small animal orthopaedics today. Several different techniques are available for the treatment of cranial cruciate ligament rupture in dogs. In the last few decades, various surgical techniques have been developed or adopted from human orthopaedics. However, according to up to date literature, no optimal technique has been identified yet. While some techniques are well reported, information about others is lacking. In this research, our aim was collect more information about a relatively new surgical method, *circular tibial tuberosity advancement* (cTTA) as well as to explore its complications and to compare it with other surgical techniques, such as *tibial tuberosity advancement rapid* (TTA-rapid).

The original technique of cTTA was described in 2010 by an Italian veterinarian, Massimo Petazzoni. Apart from the aforementioned original paper, there is only one detailed study about cTTA published in 2013 by Rovesti et al. Accordingly, there are only few data on cTTA technique in the literature. TTA-rapid technique, the other subject of our research was described in 2015 by Samoy et al. Since then, a number of studies have been published about the outcomes and complications of TTA-rapid. Both cTTA and TTA-rapid have evolved from *tibial tuberosity advancement* (TTA), a technique described in 1976 by Maquet, originally applied in human orthopaedics. It was first used in the treatment of cranial cruciate ligament rupture in dogs in 2002, as reported by Montavon, Demur and Tepic. The technique described in the latter is somewhat complicated, and requires a number of specialised implants, which is probably why the development of modified versions, including cTTA and TTA-rapid was pursued by researchers.

Our research consisted of three parts, a clinical study, a pilot study for a biomechanical study, and a biomechanical experiment.

1. Clinical study

The objective of our clinical study was to determine the complications of the first 30 tibial tuberosity advancement rapid (TTA-rapid) and circular tibial tuberosity advancement (cTTA) procedures performed by our team, and to compare the results with the findings reported in the literature. Our plan was to describe the steps of the preoperative planning of cTTA to detail as well as the steps of the surgical technique, as its description was only partial in the original publication.

This research was based on 30 procedures in each group. All dogs were client-owned. Data were collected of cases that had a minimum follow-up period of 3 months. Intraoperative (IO) and postoperative (PO) complications were assessed, with the latter divided into two subgroups: major and minor. As the implant used by our team was not the same type used in the original publication we adopted the term *modified cTTA* (mcTTA) to refer to our own technique.

Results of the the TTA-rapid group:

- IO complications 23.3% (7/30)
- Major PO complications 13.3% (4/30)
- Minor PO complications 16.7% (5/30)

Results of the mcTTA group:

- IO complications 0% (0/30)
- Major PO complications 3.3% (1/30)
- Minor PO complications 20% (6/30)

Comparing the complication rates, we found that there was a significant difference between the two groups in the occurrence of IO complications ($P = 0.01054$); however, there was no significant difference in the incidence of major ($P = 0.3533$) and minor ($P > 0.9999$) PO complications between groups. Our results are consistent with the findings reported in the literature and suggest that both techniques are efficient and carry a relatively low complication rate. Both techniques are safe to use in clinical practice, but mcTTA carries a lower IO complication rate.

We have found that a major PO complication, i.e. the transverse fracture of the tibia, occurred twice in the TTA-rapid group, while in the mcTTA group a single tibial fracture was recorded as a *minor* PO minor complication, which had already healed by the time of the follow-up examination. This prompted the question whether or not the incidence of transverse tibial fractures in the PO period is similar with the two techniques. According to our hypothesis, a post-operative transverse tibial fracture is more likely to occur with TTA-rapid than with mcTTA. As the first step of the biomechanical experiment, we performed a pilot study.

2. Biomechanical pilot study

The objective of the pilot study was to determine baseline data and settings. Six pairs of tibiae of dogs between 15 and 35 kg body weight were used in a cadaver study. Three groups were created with 4 tibiae in each group; intact (Group 1), osteotomy of the tibial tuberosity and tibial crest (Group 2) and TTA-rapid (Group 3). The tibiae were placed under

static axial compressive loading, applied until failure. The force required to break tibiae was termed maximal force (F_{max}).

Mean F_{max} was

- 8193.25 ± 2082.84 N in group 1
- 6868.58 ± 1950.44 N in group 2
- 7169.71 ± 4450.39 N in group 3

The sample size was small for a statistical analysis but as a preliminary result, we have determined the force (F_{max}) required to break canine tibiae. Furthermore, we hypothesised that osteotomies (group 2 and 3) result in weakening of the structure of the tibia.

3. Main biomechanical study

The aim of our biomechanical study was to determine the effect of TTA-rapid and mcTTA on the structural integrity of the tibia. In a cadaver study, three groups were created with 10 tibia in each: Group 1 with native tibiae, Group 2 with tibiae modified with TTA-rapid and Group 3 with tibiae modified with mcTTA. All tibiae were subjected to static axial compression. The force required to break the tibiae was termed maximal force (F_{max}). The mean and standard deviations of F_{max} are as follows:

- Group 1: 11573.92 ± 1962.68 N
- Group 2: 12480.97 ± 4169.96 N
- Group 3: 11842.61 ± 3861.27 N

We compared the mean F_{max} values of the groups, but the difference was not statistically significant (native/TTA-rapid: $p = 0.5632$; native/mcTTA: $p = 0.8474$; TTA-rapid/mcTTA: $p = 0.7344$). Displaying the data on a boxplot diagram, however, it is apparent that in Groups 2 and 3 (the modified groups), the dispersion of the values is notably wider than in Group 1 (the native group), therefore we also compared these results. Comparison of the dispersion values resulted a significant difference between Groups 1 and 2 ($p = 0.0372$), while this was not significant between Groups 1 and 3 ($p = 0.0564$) or Groups 2 and 3 ($p = 0.8171$). However, the difference between Group 1 and 3 was notable. Therefore, it can be said that bones modified with TTA-rapid or mcTTA failed either under a much lower or a much higher compressive force than native (i.e. intact) tibiae.

As a conclusion, it can be stated, that both methods may be used safely in clinical practice owing to generally low complication rates, however, in the case of mcTTA, the incidence of IO complications is significantly lower. With regards to tibial fracture as a complication, no significant difference was found between surgical techniques. The impact of each technique on the resistance of the tibia to static axial compression is not equivalent,

however. While TTA-rapid affects this to a statistically significant level, in the case of mcTTA this impact is more subtle, but still notable. Further in-depth research is needed. Apart from the surgical technique, other factors also play a role here, which may be worth exploring in the future.

New scientific results

1. We have elaborated the process of preoperative planning of cTTA (mcTTA) and the detailed description of the cTTA procedure.
2. We have recorded the short term outcomes of mcTTA.
3. We have compared the complications of TTA-rapid and mcTTA and found a significantly lower incidence of intraoperative complications with mcTTA than with TTA-rapid.
4. We have determined that the tibiae of dogs between 15 and 35 bwkg fracture at a mean of $11573,92 \pm 1962,68 \text{ N F}_{\text{max}}$ when subjected to static axial compression.
5. We have determined that the construct of the tibia in dogs between 15 and 35 bwkg is not significantly weakened by TTA-rapid or mcTTA.

Publications reporting the results of the doctoral research

1. Published/accepted publications in lectorated scientific journal with impact factor:

Zólyomi, D., Ipolyi, T., Molnár, P., Németh, T., Faragó, D., Kiss, R., Szalay, F.: **Biomechanical testing of canine tibiae: Changes resulting from different tibial tuberosity advancement techniques–Pilot study.** Acta Veterinaria Hungarica, 70 (3), 230-235., 2022.

Zólyomi, D., Ipolyi, T., Molnár, P., Papp, M., Szalay, F., Németh, T.: **Comparison of the Complication Rates of the First 30 TTA-rapid and cTTA Procedures,** Acta Veterinaria Hungarica, 2022. DOI: 10.1556/004.2022.00033

Zólyomi D., Ipolyi T., Szalay, F., Molnár P., Dunay M.P., Simon Cs., Németh T.: **cTTA: Egy új módszer kutyák elülső kereszteszál-szakadásának gyógykezelésére-1. rész: preoperatív tervezés,** Magyar Állatorvosok Lapja 8, 465–475., 2015.

Zólyomi D., Seregi A., Ipolyi T., Csizmadia P., Diószegi Z., Solymosi N.: **VOM: szabad felhasználású ortopédiai tervező és mérő szoftver,** Magyar Állatorvosok Lapja, 137(1), 37-44., 2015.

Ipolyi T., Zólyomi D., Szalay F., Diószegi Z., Molnár P., Dunay M.P., Simon Cs., Németh, T.: **cTTA: Egy új módszer kutyák elülső kereszteszál-szakadásának gyógykezelésére-2. rész: műtéti technika,** Magyar Állatorvosok Lapja, 137(10), 595-602., 2015.

Szalay F., Zólyomi D., Ipolyi T. (2015): **A kutya térdízületének anatómiája és biomechanikai alapjai - 1. rész: anatómiai áttekintés,** Magyar Állatorvosok Lapja 137(10), 587-594., 2015.

2. Conference presentations

Zólyomi D., Ipolyi T.: **cTTA: egy új módszer kutyák elülső kereszteszál szalag szakadásának gyógykezelésére – preoperatív tervezés és műtéti technika,** MTA Akadémiai Beszámolók, Budapest, 2015.

Zólyomi D., Ipolyi T.: **cTTA: egy új módszer kutyák elülső kereszteszál szalag szakadásának gyógykezelésére – tapasztalatok 55 eset alapján,** MTA Akadémiai Beszámolók, Budapest, 2016.

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