

# Learning curve for Tibial Plateau Levelling Osteotomy based on tibial plateau angle

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### Summary

The objective of the study was to assess a single surgeon's learning curve for Tibial Plateau Levelling Osteotomy (TPLO). The criterion was the accuracy of achieving a planned tibial plateau angle (TPA) immediately after surgery and comparing it with TPAs achieved by two experienced surgeons. The research was performed in June 2023 through literature in Google Scholar, ScienceDirect, Pubmed and Textbooks Tobias and Fossum using the keywords TPLO, learning curve and training. No similar studies have been described for TPLO surgery. The study was designed as a retrospective blinded case series with two case controls based on dogs with cranial cruciate ligament disease that had TPLO surgeries (n = 140). Medical records and radiographs of the first 100 TPLO surgeries performed by surgeon A (author) without direct supervision were reviewed, and consecutive numbers from 1 to 100 were allocated (November 2017–July 2020). Records and radiographs for the last 20 cases of two experienced surgeons B (RCVS Diplomate) (March 2019–June 2020) and C (ECVS Diplomate) (October 2019–June 2020) were used as two comparison groups (further numbers were allocated). Statistics were calculated, and a graph was created to show the learning curve. Improvement in the accuracy of achieving the desired TPA was seen after the first 40 cases, but the learning curve plateaued after around 60 cases and TPAs were comparable with those achieved by more experienced surgeons. The clinical relevance of this study is that supervision during TPLO surgeries should be considered for at least the first 40 cases.

**Keywords:** experience, learning curve, surgery, tibial plateau angle, Tibial Plateau Leveling Osteotomy

Cranial cruciate ligament (CCL) disease is the most common cause of hind limb lameness (3,4). Multiple treatment options have been described, with a new approach or modifications appearing each year. The main treatment options include conservative treatment, extracapsular methods (lateral suture stabilization, Arthrex TightRope, etc.), intracapsular methods and osteotomy techniques (TPLO, tibial tuberosity advancement TTA, CORA-based osteotomy CBO, MMP etc.)

Lateral suture stabilization is the most commonly performed technique for the treatment of CCL disease in veterinary medicine, but Tibial Plateau Leveling Osteotomy (TPLO) described in 1987 (11, 13) is one of the most commonly performed surgical techniques in referral centres (6) and can produce the best long-term outcome for the patient (8, 16).

TPLO neutralises cranial tibial thrust by changing the tibial plateau angle (TPA), which involves surgical planning, osteotomy, rotation and stabilization of the bone fragment. Thus TPLO surgery is signifi-

cantly more demanding than extracapsular methods. Unfortunately, the learning process is poorly described.

The purpose of this study was to assess a single surgeon's learning curve for achieving the planned TPA immediately after TPLO surgery and compare it with TPAs achieved by two experienced surgeons. The hypothesis was that the postoperative TPA would become closer to the desired 5 degrees with the surgeon's increasing experience.

### Material and methods

**Study design.** All surgeries were performed at the same specialist orthopedic referral practice. Surgeries were performed in the same way throughout the study period. Medical records and radiographs for the first 100 TPLO surgeries performed by surgeon A (author) without direct supervision were reviewed and consecutive numbers from 1 to 100 were allocated (November 2017–July 2020). Records and radiographs for the last 20 cases of two experienced surgeons B (RCVS Diplomate) (March 2019–June 2020) and C (ECVS Diplomate) (October 2019–June 2020) were

used as two comparison groups (further numbers were allocated).

**Inclusion criteria.** Dogs were included in the study if they had confirmed cruciate ligament disease treated by TPLO, complete medical records, pre- and immediate postoperative radiographs. Patients were excluded for incomplete medical records or radiographs.

**Radiography and measurements.** Orthogonal radiographs of the affected limbs were obtained with the stifle and hock included in each of them. Radiographs were obtained for preoperative measurements, as well as for immediately postoperative ones. Special care was taken to superimpose femoral condyles on the mediolateral views. All radiographs were calibrated using an orthopedic ball.

Each pair of pre- and immediate postoperative mediolateral radiographs free of patients' details were given a randomly allocated number from 1 to 140 using the randomizer.org website to blind the study. The template of the numbers was hidden. The TPA was measured on each radiograph using computer software (DICOM Viewer). This program automatically gives the distance of rotation needed to achieve a postoperative TPA of 5 degrees. Measurements were based on Slocum's description (Slocum 1987), which used mechanical axis and tibial plateau to determine the TPA. All measurements were performed and recorded by the author. After obtaining all results, the randomly allocated numbers were reversed to primary numbers, using a previously prepared template that gave the chronological order of the first 100 surgeries for surgeon A and control groups of 20 surgeries for surgeons B and C. Cases from group A were divided (in chronological order) into five groups from A1 to A5, with 20 cases in each group.

A value of 5 degrees was deducted from each postoperative angle to show deviation from the desired outcome (TPA post – 5). Absolute values in each group were allocated to one of the following outcomes: 2 or less – very good, above 2 to 4 – good, above 4 to 6 – acceptable, above 6 – poor.

The mean and the standard deviation were calculated for each group. Spreadsheet software (Open Office Cal, Apache Software Foundation) was used for data management and charting.

**Surgical technique.** All surgeries were performed without a scrub assistant and in the same manner. After measuring the TPA (as described above), the osteotomy position was determined as presented by Kowaleski (5) using the tibial intercondylar tubercles and the attachment of the patella tendon as landmarks.

An appropriate saw radius was chosen from 21-30 mm, ensuring that the saw blade was as big as possible, but the remaining tibial tuberosity was not smaller than 10 mm. Each patient underwent a medial arthrotomy to confirm the initial diagnosis and meniscal examination. The next step was the preparation and identification of the osteotomy site. The Sartorius muscle was elevated, and a TPLO jig

was applied. A hypodermic needle was placed in the intercondylar notch, and the patella tendon attachment was located. Both of these points gave the surgeon landmarks to measure and mark the osteotomy site according to the previous measurements. After performing partial osteotomy, the distance for rotation was marked using a Slocum rotation gauge and a bone scribe. The osteotomy was completed, and the bone fragment was rotated to a new position using Elis's pin as a rotation device. When the bone fragment was in the position, a K wire was placed proximal to the insertion of the patella tendon to the proximal bone fragment as a temporary fixation. Point-to-point reduction forceps were used to compress the osteotomy site, and a Synthes locking TPLO plate was used for the final stabilization of the osteotomy. The wound was flushed and stitched in a routine fashion.

## Results and discussion

All cases from groups A and C met the inclusion criteria. One case from Group B had a poor quality post-operative radiograph because of equipment malfunction, so the next case was included for research.

Breeds included were Labrador Retriever (43), Golden Retriever (16), Crossbreed (17), Husky (7), English Springer Spaniel (7), Border Collie (6), German Shepherd (5), Dog de Bordeaux (5), Staffordshire Terrier (4), Rottweiler (4), New Foundland (4), Akita (3) and other breeds (29).

The weight distribution was 16.6-72.2 kg. TPLO blades used were 21-30 mm, with a median of 24 mm.

The mean, standard deviation and individual deviation from 5 degrees for each group are presented in Table 1. Significant improvement in the accuracy of achieving the desired TPA was seen after the first 40 cases, but the learning curve flattened after around 60 cases, and TPA's were comparable with those achieved by more experienced surgeons. This can be seen from the change in the value of standard deviation for „TPA post – 5” from 3.24 (group A1) and 3.23 (group A2) through 1.62 (group A3) to 1.35 (group A4) and 1.33 (group A5). Standard deviation values in the comparison groups were 1.41 in group B and 1.35 in group C. After allocating each individual absolute value of “TPA post – 5” to one of four groups, we can see again that, with increasing experience, the amount of poor and

**Tab. 1. Summary of results from individual groups**

Group	Mean	Standard deviation “TPA post – 5”	“TPA post – 5” (absolute values in degrees)			
			2 or less	above 2 to 4	above 4 to 6	above 6
A1	8.08	3.24	8	4	4	4
A2	7.05	3.23	8	7	3	2
A3	6.30	1.62	14	5	1	0
A4	4.43	1.35	19	1	0	0
A5	4.25	1.33	19	1	0	0
B	4.95	1.41	18	2	0	0
C	4.25	1.35	18	2	0	0

acceptable outcomes drops after 40 cases, and then further improvement is seen around case 60, when it becomes comparable to that achieved by the experienced surgeons.

The evidence of the surgeon's improvement in achieving the desired TPA is more obvious on a chart showing rolling "TPA post - 5" (as absolute values) over the last

100 surgeries (Fig. 1). For comparison, the chart is showing the standard deviation of „TPA post - 5" for surgeons B and C.

Many papers describing TPLO there claim that this technique has a steep learning curve. Unfortunately, no paper gives any indication of how fast the progress is. Some studies show a decrease in surgical complications with the surgeon's increasing experience (1, 7), but the papers do not focus on the functional outcome of the surgery.

This study shows improvement in achieving the desired TPA during TPLO surgery with the number of surgeries performed by the surgeon. Improvement in outcome was achieved after around 40 cases, but the final flattening of the learning curve and results comparable with those achieved by more experienced colleagues were noted after around 60 cases. It is worth noting that the flattening of the learning curve is evidenced mostly by the increasing probability of achieving a „very good" or „good" TPA during surgery, based on the grading system adopted.

Achieving a correct TPA is the main aim of TPLO surgery. The 5-degree target was chosen based on previous reports (9, 12). The grading scale from "very good" to "poor" was presented in absolute values because when the TPA decreases towards 0, caudal tibial subluxation results from caudal tibial thrust, and may predispose the caudal cruciate ligament to injury (15), and when the TPA approaches 14 degrees, cranial tibial thrust may not be eliminated (2, 10). Thus, both a positive and a negative TPA - 5 may affect the outcome of the surgery.

Achieving the desired TPA during TPLO surgery may be influenced by many factors, for example, the position of the osteotomy, intraoperative measurement methods or bone fragment rotation. To minimize the effect of these variables, all surgeons had performed surgeries in the same fashion.

All TPA measurements were performed by the author. To minimize bias, cases were blinded, and

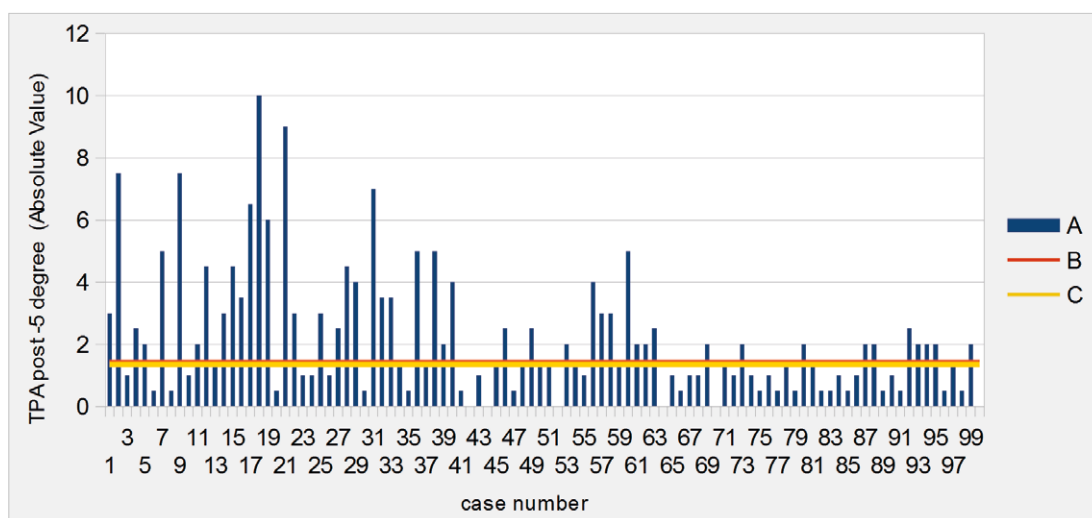


Fig. 1. Improvement in achieving the desired postoperative TPA with experience

the software for TPA measurements was used, as computer-based measurements reduce variability in measurement results (14).

The first 100 surgeries were performed by surgeon A (the author) without a scrub assistant or direct supervision by another surgeon. An experienced surgeon was present in the building and could help during surgery if needed. Surgeon A was supervised during his first three surgeries by an RCVS Diplomate. These surgeries were not included in the study.

Patient weight distribution, blade type, and Left to Right percentage were similar across surgeons A, B and C.

As a general principle, surgeons in this study performed TPLO surgeries on the patient where a 21 mm blade or higher could be used (3.5 mm locking plate), and if a smaller blade was required, the surgery of choice was Cranial Closing Wedge Osteotomy (CCWO). That is why in this study only blades 21, 24, 27 and 30 were used.

There are several limitations to our study, including its retrospective nature. It is based on the performance of only one inexperienced surgeon during the study period. This surgeon was performing other similar surgeries, such as CCWO, during the time of the study, which may have positively influenced his results.

Another criticism of the study is that it focuses on the single value TPA, and does not try to explain factors that improve the learning curve, such as the positioning of the osteotomy, surgeries performed previously by surgeon A or the frequency of TPLO surgeries. Hopefully, further studies will provide more in-depth knowledge about other values that influence the learning curve for TPLO surgeries.

Despite its shortcomings, this study has demonstrated a learning curve for achieving the desired TPA in TPLO surgery. This may be useful for training surgical residents. Further analysis for a larger number of surgeons should be considered in the future.

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