

# DEVELOPMENT OF A LASER REFLECTANCE SYSTEM TO MEASURE THE CROSS-SECTIONAL AREA OF SOFT TISSUE

Gabriel Pokhai<sup>1,2</sup>, Karen Gordon<sup>1</sup>, Michele Oliver<sup>1</sup>

<sup>1</sup>School of Engineering, University of Guelph, Guelph, ON, Canada

<sup>2</sup>Email: [gpokhai@uoguelph.ca](mailto:gpokhai@uoguelph.ca)

## INTRODUCTION

Accurate cross-sectional area (CSA) measurements are required to determine biomechanical properties of soft tissue. Measuring the CSA of tendons and ligaments is difficult because they are irregularly shaped and easily deformed. Of the many methods of measuring CSA that have been reported, there are concerns with contact methods that can deform the specimen, and non-contact methods that require geometric assumptions (Moon et al., 2006). The objective of this work was to design and verify a non-contact laser reflectance system (LRS) for accurate CSA measurement of soft tissue.

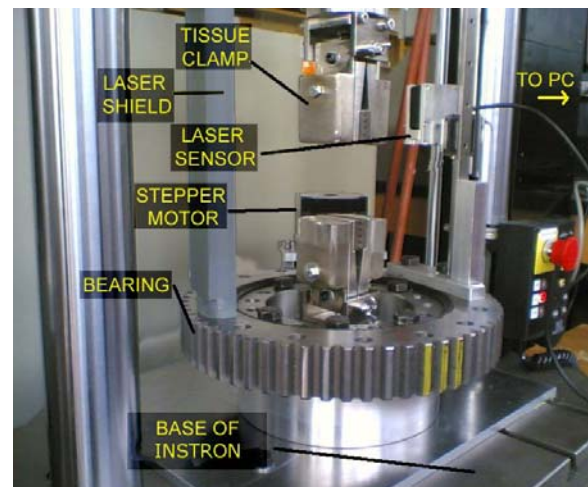
## METHODS AND PROCEDURES

The system includes a Keyence LB-10 laser micrometer (Keyence Corp., Woodcliff Lake, NJ), which is mounted on a turntable bearing (Kaydon Corp., Muskegon, MI) and rotated with a stepper motor (Automation Direct, Cumming, GA). The entire assembly is mounted on an Instron 8872 servo-hydraulic testing machine (Instron Corp., Canton, MA) (Figure 1). Laser readings are collected by a personal computer, and along with the angle of rotation are used to calculate the CSA via Reimann sums with Microsoft Excel spreadsheets (Microsoft Corp., Redmond, WA).

Machined metallic specimens of various sizes were placed in the centre of the assembly and the laser was orbited at 5° angle increments around the specimen. The system was validated by repeating the measurements with a previously reported casting method (Goodship and Birch, 2005).

As a “gold standard” measurement, photographs of the specimen cross-sections were taken with 10 megapixel digital camera and CSA values were calculated using ImageJ image analysis software (National Institutes of Health, Bethesda, MD). The CSA values from the LRS and the casting method were compared with these values.

As a preliminary study, the CSA of five bovine deep digital flexor tendons (DDFT) were measured with the LRS. The tendons were first stained with ink to prevent



**Figure 1.** Laser reflectance system, as installed on Instron testing machine.

Shape	Photograph CSA	Laser CSA	Laser Error (%)	Casting CSA	Casting Error (%)
Small Circle	29.95	29.55	1.32	29.35	2.00
Large Circle	506.75	508.08	0.26	501.91	-0.95
Kidney Bean	307.18	316.15	2.92	324.79	5.73

**Table 1.** CSA measurements of various metallic shapes. CSA is given in mm<sup>2</sup>.

penetration of the laser beam into the specimen (Moon et al., 2006). Transverse sections of the mould and tendon were cut at the same level measured with the LRS and digital images of both were taken. The CSA values of these sections were calculated in image analysis software as above.

A 2-way analysis of variance (ANOVA) was performed to determine if there were significant differences between the CSA values obtained from the LRS and the casting method ( $p \leq 0.05$ ), for both machined and soft tissue specimens.

## RESULTS

The LRS was able to measure circular areas of the metallic specimens to within 2% and a complex “kidney bean” shape to within 3% (Table 1). No significant differences were found between the LRS and casting methods ( $p = 0.448$ ).

The LRS measured the CSA of the tendon specimens with an average error of  $1.11 \pm 8.25\%$  relative to the gold standard (Table 2). The CSA as determined by the casting method had an average error of  $11.22 \pm 3.83\%$  (data not shown). Statistical analyses again showed no significant difference between measurement methods ( $p = 0.052$ ).

## DISCUSSION

The LRS produced CSA values with minimal errors equivalent or less than the established casting method for both metallic

Tendon	Photograph CSA	Laser CSA	Laser Error (%)
1	187.88	200.30	6.61
2	155.54	160.04	2.89
3	167.96	149.61	-10.93
4	158.41	153.75	2.94
5	159.61	175.44	9.92
Mean (SD)	165.88 (13.14)	167.83 (20.64)	1.11 (8.25)

**Table 2.** Tendon CSA measurements. CSA is given in mm<sup>2</sup>.

and soft tissue specimens. The accuracy of both methods decreased when measuring the tendon specimens.

## SUMMARY

A soft tissue laser measurement system was designed and successfully validated against an existing casting measurement method, producing accurate CSA measurements for several machined specimens of various shapes and radii. The system’s installation on an Instron testing machine will permit future studies where CSA of tendon specimens is measured simultaneous with tensile testing to facilitate calculation of true stress values.

## REFERENCES

- Goodship, AE and Birch, HL. (2005). *J Biomech*, 38:605-8.  
 Moon, DK et al. (2006). *J Biomech*, 39:3071-5.