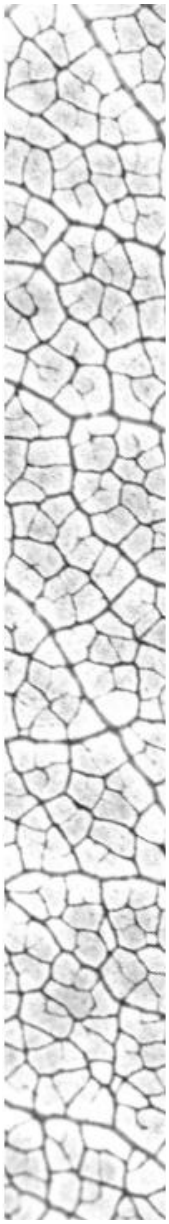

EurAsian Journal of BioSciences
Eurasia J Biosci 14, 3469-3473 (2020)

Reconstruction and augmentation in the proprioceptive function of the knee joint after knee arthroscopy surgery on partially torn anterior cruciate ligament

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Abstract

Background: Anterior cruciate ligament (ACL) injury is the most common ligament injury. The changes in motor and sensory behaviors after ACL reconstruction are due to the lack of proprioceptive information as a result of ACL lesions and/or ACL graft substitutes. **Objectives:** This study aims to determine the effects of proprioceptive and joint stability after ACL augmentation using joint position sense (JPS) and threshold to detect passive motion (TTDPM) as the indicators. **Methods:** This study was conducted using an observational study design applied to patients. The study design used was a cross-sectional study in two populations. The statistical test used was the Independent T-Test. **Result:** There was a deficit of 3.3±4.7 when JPS was tested at 30 degrees in the augmentation group and -3.6±3.1 at 30 degrees in the reconstruction group (p=0.013); -5.4±6.1 at 45 degrees in the augmentation group and -2.5±5.4 at 45 degrees in the reconstruction group (p=0.033); -4.4±7.5 at 60 degrees in the augmentation group and -3.6 ±5.0 at 60 degrees in the reconstruction group (p=0.02). On the other hand, in the TTDPM measurements related to the Golgi complex of the quadriceps muscle, there was a significant difference (p=0.011) at 6.5±2.4 in the augmentation group and 4.1±1.3 in the reconstruction group. **Conclusion:** This study shows that the effects of proprioceptive and joint stability after practicing ACL augmentation surgery are more effective than ACL reconstructive surgery as assessed by the JPS and TTDPM indicators.

Keywords: anterior cruciate ligament, augmentation, proprioceptive, joint stability

Utomo DN, Wibowo PA, Andrianus J, Desnantyo AT, Tinduh D, Ferdiansyah (2020) Reconstruction and augmentation in the proprioceptive function of the knee joint after knee arthroscopy surgery on partially torn anterior cruciate ligament. Eurasia J Biosci 14: 3469-3473.

INTRODUCTION

Knee injury is one of the problems in the musculoskeletal system, which is often reported in outpatient services with a prevalence of 48 per 1,000 patients annually (Feller, & Webster, 2008, Ingle, & Nandu, 2009). Among all knee injury cases, 9% are ligament injuries in which the anterior cruciate ligament (ACL) appears as the most frequent ligament injury (Feller, & Webster, 2008, Milner, 2019).

Several studies conducted in patients with ACL tears have shown a proprioceptive dysfunction in the knee joint (Bonfim, Paccola, & Barela, 2003). According to evidence-based practice, almost half of all knee ligament injuries are ACL tears and this is the biggest cause of knee instability that can result in changes in function, damage to other joint structures, and will further affect daily activities and walking function (Anitua, et al. 2004. AndersVenbrocks, & Weinberg, 2008. Utomo, Tinduh, & Wibowo, 2017). ACL is known to contain a mechanoreceptor, consisting of the Pacinian corpuscles, Golgi tendon organ, and Ruffini nerve endings which is located on a stump (ACL remnant that is still attached) in Tibia. These receptors contribute to the proprioceptive sense of the knee joint (Feller, & Webster, 2008, Duthon, et al. 2006, Patestas& Gartner, 2006; Tanimu, & Akujuru, 2018).

Most studies on knees with ACL tears indicate a decline in the proprioceptive function of the knee joint (Bonfim, Paccola, & Barela, 2003). One of the treatments to care for ACL tears is ACL reconstruction, which is the act of replacing a damaged ACL through grafting. According to a study, there is a change in motor and sensory behaviors after ACL reconstruction which is thought to be due to a lack of proprioceptive information as a result of ACL lesions and/or ACL graft substitutes (Bonfim, Paccola, & Barela, 2003, Setiawati, et al. 2017, Mardina, et al. 2014).

Received: November 2019
Accepted: March 2020
Printed: September 2020

Quantitative evaluation is required to assess the proprioceptive restoration. Previous studies have introduced proprioceptive evaluation of the knee joint using joint position sense (JPS) to reproduce passive or active angle of the knee joint before evaluating the joint position sense and threshold to detect passive motion (TTDPM) to evaluate the joint motion (kinesthesia). Knee joint proprioception is essential to modulate and activate muscle accurately which in turn will provide adequate neuromuscular control of the knee joints for various knee joint positions and movements, and finally, the ability to do physical tasks (Ochi, et al. 2006). However, proprioceptive dysfunction is still detected in the mid-range motion of the knee joint (Weng, et al. 2015). There is still controversy on the effects of ACL reconstruction on the proprioceptive function of the knee joint.

Tissue engineering is widely developed in the Orthopedics field. Progressively, the results of the ACL graft become better and thus reduce the recovery time. ACL augmentation technique is expected to increase stability in the knee joint by maintaining proprioceptive function. Some developed ACL reconstruction techniques are believed to restore the function of the knee joint. Meanwhile, Anterior Cruciate Ligament Augmentation is considered to restore the proprioceptive function of the knee joint, which can improve the afferent input needed for joint stability and proprioception. A histological study has revealed the mechanoreceptor regeneration manifestation in the ACL graft, which is detectable from week 4 after reconstruction (San Martín-Mohr, et al. 2018). This study aims to identify the effects of proprioceptive and joint stability after ACL augmentation using JPS and TTDPM indicators.

METHODS

This study was conducted using an observational study design applied to patients. The study design used was a cross-sectional study in 2 populations. The study population was all patients with an ACL tear on the knee joint who underwent ACL reconstruction and ACL augmentation in Surabaya. From the total sample, those who have undergone ACL augmentation and ACL reconstruction are collected separately. The anterior of two treatments on the samples then being examined. The selection of the research sample was following the inclusion and exclusion criteria. Furthermore, the samples that met these criteria were divided into two groups. Group 1 received ACL augmentation treatment whereas Group 2 received ACL reconstruction treatment. Subsequently, both results were measured using proprioceptive tests six weeks after surgery. The results of both groups were compared afterwards. This study has complied with the research ethics procedure.

Table 1. Normality Test Results of the Augmentation Group

Variable	Augmentation Group		Normal Knees Group	
	x±SD	p	x±SD	p
JPS 30 °	-3.350±4.796	0.813	-0.360±6.916	0.714
JPS 45°	-5.460±6.081	0.842	0.100±6.270	0.848
JPS 60°	-4.460±7.519	0.627	-2.850±6.104	0.980
TTDPM	6.510±2.436	1.000	6.760±5.515	0.161

Table 2. Normality Test Results of the Reconstruction Group

Variable	Reconstruction Group		Normal Knees Group	
	x±SD	p	x±SD	p
JPS 30 °	-3.640±3.131	0.582	-2.770±4.831	0.331
JPS 45°	-2.580±5.426	0.858	1.150±6.146	0.629
JPS 60°	-3.670±5.034	0.458	-1.930±7.240	0.993
TTDPM	4.130±1.336	0.971	6.840±6.062	0.533

Table 3. Homogeneity test results of ACL augmentation and reconstruction groups

Variable	Augmentation Group		Reconstruction Group		p
	x	SD	x	SD	
JPS 30 °	1.670	5.809	-4.100	2.419	0.031
JPS 45°	2.340	8.001	-4.240	4.106	0.051
JPS 60°	3.460	8.083	-6.910	5.034	0.097
TTDPM	6.910	2.661	4.130	1.336	0.016

Note: Data are considered significant if p>0.05

Table 4. Statistical test results of the reconstruction group compared to normal knees

Variable	Reconstruction Group		Normal Knees Group		Paired t-test
	min-max	x±SD	min-max	x±SD	
JPS 30 °	-7.00-2.30	-3,640±3,131	-14.70-2.70	-2,770±4,831	0.437
JPS 45°	-13.00-4.30	-2.580±5.426	-13.70-7.70	1.150±6.146	0.033
JPS 60°	-13.00-2.30	-3.670±5.034	-16.00-10.00	-1.930±7.240	0.347
TTDPM	2.10-6.60	4.130±1.336	1.30-21.40	6.840±6.062	0.120

Note: data are considered significant if p>0.05

The analysis results are subsequently presented in tabular and graphic form. This research was conducted to identify the effect of ACL Remnant Preservation on Proprioseptic Test. The statistical test used was the Independent T-Test since the Nominal Independent Variable, and the Dependent Variable are ordinal variables.

RESULTS

In this study, the researchers compared the results of JPS and TTDPM measurements between the ACL Augmentation group and the ACL reconstruction group. Both data were continuous data and, thus, the statistical test used was the Independent T-Test. This test was a parametric test in which the data must be normally distributed.

The analysis indicates that both data groups were normally distributed. To this extent, the Independent T-Test was relevant. The test results revealed that there was no difference (all obtained p>0.05) between the JPS results at 30°, 45°, 60° and TTDPM between the reconstructed knees and normal knees.

The test results in **Table 5** indicate that there is no difference (all obtained p>0.05) between the JPS at 30°,

Table 5. Statistical test results of augmentation group compared to normal knees

Variable	Augmentation Group		Normal Knees Group		Paired t-test
	min-max	x±SD	min-max	x ± SD	
JPS 30 °	-13.70-3.30	-3.530±4.796	-14.70-9.70	-0.360±6.916	0.146
JPS 45°	-17.30-2.00	-5.460±6.081	-13.70-5.70	0.100±6.270	0.015
JPS 60°	-15.00-13.30	-4.460±7.519	-16.00-6.30	-2.850±6.104	0.552
TTDPM	03.10-10.70	6.510±2.436	02.40-21.40	6.760±5.515	0.897

Note: data are considered significant if p<0.05

Table 6. Statistical test results of the augmentation group compared to the reconstruction group

Variable	Augmentation Group		Reconstruction Group		Independent t-test
	x±SD	min-max	x ± SD	min-max	
JPS 30 °	-3.350±4.796	-13.70-3.30	-3.640±3.131	-7.00-2.30	0.013
JPS 45°	-5.460±6.081	-17.30-2.00	-2.580±5.426	-13.00-4.30	0.033
JPS 60°	-4.460±7.519	-15.00-13.30	-3.670±5.034	-13.00-2.30	0.029
TTDPM	6.510±2.436	03.10-10.70	4.130±1.336	2.10-6.60	0.011

Note: data are considered significant if p<0.05

45°, 60° and TTDPM between the knees that have been augmented with ACL and normal knees.

The test results in **Table 6** suggest that there is a difference between the JPS at 30° (p=0.013), 45° (p=0.033), 60° (p=0.029) and TTDPM (p=0.011) between the knees that have undergone ACL augmentation and the knees that have undergone ACL reconstruction.

DISCUSSION

The study results indicated that there were statistically significant differences in JPS and TTDPM examinations between ACL augmentation surgery and ACL reconstructive surgery. Proprioceptive and kinesthesia arose from sensory receptors stimulation in the skin, ligaments and joint capsules, and interactions between afferent and efferent signals. Sensory receptors converted mechanical receptors into electrical signals which were then transformed into cortical pathways and reflex arcs through different types of nerve fibers that were specific to each modality. Proprioceptive and kinesthesia in the hypothesis had a contribution to neuromuscular control because it was essential for joint functional stability (Ochi, et al. 2006).

The success of ACL functional after arthroscopy surgery depend on several factors, including 1. Anatomic Graft Placement accompanied by adequate fixation, 2. Graft incorporation, 3. revascularization, and 4. Ligamentization. There was no significant comparison in the comparison of JPS and TTDPM measurements between the outer side knee injury of the reconstruction group and the normal knee (p> 0.05). It was due to nerve reinnervation in ACL reconstruction and/or nerve reinnervation in capsules and ligaments, which affected the accuracy in JPS and TTDPM assessments. This result is consistent with previous studies (Ochi, et al. 2006, Hopper, et al. 2003). However, based on the results of JPS and TTDPM assessments in the reconstruction group, there was still a deficit (far from zero). It was consistent with studies conducted on subjects after ACL reconstruction. Previous research has also concluded that there was still a proprioceptive deficit in subjects after ACL reconstruction with a period between 12 to 30 months after arthroscopy surgery (Bonfim, Paccola, & Barela, 2003).

This study is inconsistent with the studies that reported no proprioceptive dysfunction of the knee joints in patients after ACL reconstruction with a period of 12 to 16 months after surgery as indicated by JPS in a standing position (weight-bearing). It could be caused by differences in the measurement period in which in the 12^{th} to 16^{th} months after surgery, there has been a complete regeneration of the mechanoreceptors. Furthermore, the method used for the JPS indicator in a standing position provided sensory input from the extra-articular structure, which helped determine the joint position more accurately (Hopper, et al. 2003).

In this study, there was a significant difference in the comparison of JPS between augmentation and reconstruction groups (p<0.05). It was presumably caused by the proprioceptive remained in the ACL remnants that were not ruptured in which it benefited patients to recover more quickly. Besides, by preserving some ACL remnants, it enhanced biomechanical strength after surgery. Thus, patients could carry out rehabilitation programs earlier and can recover sooner (Colombet, et al. 2010).

The TTDPM means in the two groups did not indicate significant differences. There were two reasons behind this. First, the population of mechanoreceptors in ACL was dominated by Ruffini endings that played an important role in stimulating joint positions of both statically and dynamically. The population of Pacini as a mechanoreceptor which was essential in the dynamic motion of the joints was less when compared to Ruffini endings. After the reconstruction, Pacini regenerated faster than Ruffini endings (Neumann, 2013). It caused TTDPM or after reconstruction kinesthesia to be preserved, although the population before the injury was less than Ruffini. Secondly, the level of injury related to the ACL structure was the reason for the inconsistent results in this study. Certain individuals could count to a greater extent or receive afferent input more proportionately than their ACLs and the other related capsule ligaments were found damaged.

Previous studies have revealed significant variability in the innervation patterns of ligaments in humans, including ACL, and subsequent investigators have revealed differences in the number of mechanoreceptors between different knees examined (Neumann, 2013). Additionally, because of the individual anatomical structure, the degree of ligament laxity, or certain patients' muscle might be able to compensate through the input from the muscle or tendon receptor, which established the varied functional results after ACL surgery. Some patients were aware to achieve hamstring control, and this has been associated with a better prognosis. Third, the TTDPM assessment in this study used a Cybex isokinetic dynamometer in which its settings must be operated toward knee flexion before the machine set in motion by itself. Thus, the subject could recognize when the machine started to move, and this caused an assessment bias.

The results of this study provide information about the benefits of ACL preservation of proprioceptive function in the patients' knees after ACL augmentation and the benefits of early rehabilitation with the purpose that patients can return to their activities sooner. This study still used a limited number of samples, so further research on the same topic is highly recommended.

CONCLUSION

This study suggests that the effects of proprioceptive and joint stability in ACL augmentation surgery are more effective compared to ACL reconstruction surgery, as evidenced by the JPS and TTDPM indicators.

ACKNOWLEDGEMENT

This study conducted with self-funding by authors. Dwikora Novembri Utomo gave critical comments when the study concucted. All aouthors have agreed on the final form of the article manuscript.

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