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Strength, stability and hopping after inside-out meniscus repair show good to excellent recovery which support the guiding principle “Save The Meniscus”: a clinical biomechanical outcome research

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Faculty Disclosure Information

- The authors have nothing to disclose in relation to this study.

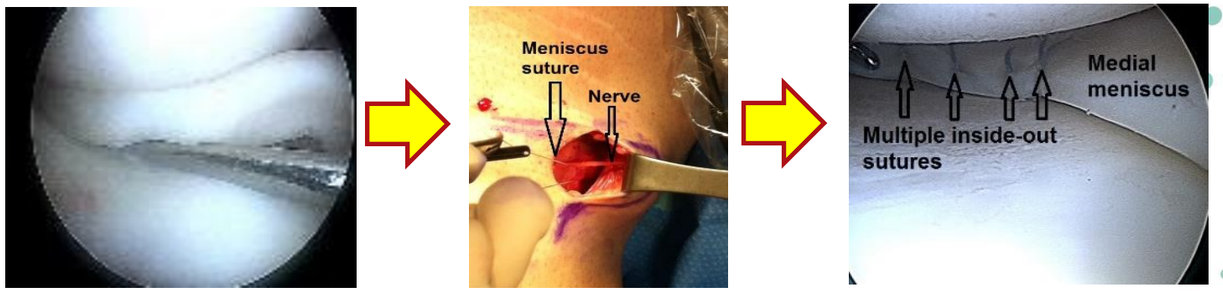
Introduction

- Meniscus repair is becoming increasingly popular since it is associated with long-term preservation of the articular cartilage and it promotes cost-effective management of medical resources (*Deviandri R, KSSTA 2023*).
- Nevertheless, repairing the meniscus is more demanding than simple meniscectomy, it involves longer rehabilitation periods, and it has risks relating to repeated arthroscopy due to failed repair, as well as risks of iatrogenic lesions to the neurovascular structures.
- Thus, studies have looked for optimizing the indications for meniscus repair, in addition to favoring circular suture (i.e. inside-out or outside-in) as gold-standard technique which shows very low failure rates.
- Outcome studies following meniscus repair were commonly reporting subjective scores and rates of repeated arthroscopy whereas objective measures at minimum 2-year follow-up are lacking.

Background and driving force for this study

Inside-out technique is consistently used for repairing long meniscus tears (i.e. those requiring ≥ 3 sutures) by the senior author since 2012. Therefore, it was felt that such a cohort of patients operated for similar indications could provide a valuable database for inquiring success and failure rates of this technique, incorporating a spectrum of subjective and objective outcome measures, while limiting selection bias and heterogeneity of the repair technique.

- Hetsroni I, et al. Inside-out repair of extensive meniscal tears using posteromedial and posterolateral neurovascular protective windows. *Arth. Tech*. 2021



Purposes of this study

1. To provide holistic assessment of outcomes following inside-out repair of long meniscus tears by incorporating subjective reported measures and objective functional measures, including strength, hopping, and balance assessments.

2. To test possible associations between the subjective reported measures and the objective functional outcome measures.

3. To ultimately optimize decision-making during meniscus surgery by incorporating the subjective and objective outcomes measures, and the patient and injury demographics in machine-learning algorithms.

Study population

120 patients (127 menisci repaired)

Minimum 3 inside-out suture repair

Operated between 2012 and 2022

96♂; 24♀

MM repair = 89; LM repair = 38; Meniscus repair + ACLR = 56

78 patients (80 menisci repaired)

Operated between 2012 and 2020 (≥ 2-year FU)

67♂; 11♀

MM repair = 58; LM repair = 22; Meniscus repair + ACLR = 34

Follow-up rate 90%

42 additional patients (47 menisci repaired)

Operated between 2021 and 2022 (< 2-year FU)

Will be evaluated once they reach the "minimum 2-year follow-up"

6 patients (6 menisci: 4 MM, 2 LM) not available to FU (of which 3 living abroad)

(of these 6 patients, 2 had concomitant ACLR)

Subjective outcome scores (for the entire cohort)	Objective biomechanical measures (in 41 men with uninjured contralateral limb)
Tegner scale (0-10)	Knee peak extension torque at 60° and 180°/sec [Nm/Kg]
Marx score (0-16)	Knee peak flexion torque 60° and 180°/sec [Nm/Kg]
IKDC-subjective (0-100)	Knee extension work at 60° and 180°/sec [Joule/Kg]
KOOS-symptoms (0-100)	Knee flexion work at 60° and 180°/sec [Joule/Kg]
KOOS-pain (0-100)	Time to stability at single-legged landing [Seconds]
KOOS-ADL (0-100)	Ground reaction peak force at single-legged landing [N/Kg]
KOOS-sports (0-100)	Single-legged hop for distance [cm]
KOOS-QOL (0-100)	Limb symmetry index for all of the above measures [%]

Outcome measures

Limb Symmetry Index (LSI) = SI (%) = 2 * (Xn – Xi) / (Xn + Xi) * 100

Xn, the value of variable in the uninjured side; Xi, the value of variable in the injured side.
Perfect symmetry is achieved when SI equals zero.

Robinson RO, et al. J Manipulative Physiol Ther. 1987;10:172-176.

Preliminary clinical failure rates in the entire cohort (re-arthroscopy for resection)

Variable	n.	%	
Re-arthroscopy of all meniscus repairs	11	14	
Re-arthroscopy of meniscus repairs with concomitant ACLR	3	5	
Re-arthroscopy of medial meniscus with concomitant ACLR	3	7	
Re-arthroscopy of lateral meniscus with concomitant ACLR	0	0	
Re-arthroscopy of meniscus repairs w/o concomitant ACLR	8	20	
Re-arthroscopy of medial meniscus repairs w/o ACLR	7	24	
Re-arthroscopy of lateral meniscus repairs w/o ACLR	2	11	

Outcomes at 2 to 10-year follow-up

Failed cases were not different in:

1. Age
2. Sex
3. Smoking status
4. Tear chronicity or Tear length

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Preliminary clinical subjective outcome score values in the entire cohort

Reported Outcome Measure	
Return to pre-injury Tegner level [%]	68
Return to pre-injury Marx scores [%]	51
IKDC-subjective score [mean ± SD]	91 ± 7
KOOS – Symptoms [mean ± SD]	88 ± 9
KOOS – Pain [mean ± SD]	91 ± 8
KOOS – ADL [mean ± SD]	96 ± 5
KOOS – Sports [mean ± SD]	80 ± 18
KOOS – QOL [mean ± SD]	65 ± 19

Among patients who did not undergo resection of a "failed meniscus repair", subjective function & satisfaction was high on average

Outcomes at 2 to 10-year follow-up

Biomechanical objective outcome values in the 41 men with contralateral uninjured limb

(20 had isolated meniscus repair, and 21 had meniscus repair with concomitant ACL reconstruction)

Biomechanical variable	Isolated meniscus repair group (n.=20)	Meniscus repair & ACLR group (n.=21)
Knee peak extension torque at 60° and 180°/sec [Nm/Kg] in the operated side	252 ± 46 and 185 ± 30	233 ± 61 and 174 ± 38
Limb symmetry index [%] at 60° and 180°/sec	4 ± 14 and 2 ± 11	10 ± 23 and 7 ± 15
Knee peak flexion torque 60° and 180°/sec [Nm/Kg] in the operated side	118 ± 23 and 115 ± 91	106 ± 29 and 91 ± 25
Limb symmetry index [%] at 60° and 180°/sec	1 ± 21 and 2 ± 20	-4 ± 37 and 3 ± 19
Knee extension work at 60° and 180°/sec [Joule/Kg] in the operated side	285 ± 69 and 223 ± 36	257 ± 56 and 202 ± 49
Limb symmetry index [%] at 60° and 180°/sec	4 ± 20 and 0 ± 11	7 ± 20 and 5 ± 16
Knee flexion work at 60° and 180°/sec [Joule/Kg] in the operated side	146 ± 27 and 115 ± 25	140 ± 38 and 110 ± 33
Limb symmetry index [%] at 60° and 180°/sec	0 ± 19 and -2 ± 21	6 ± 20 and 6 ± 22
Time to stability at single-legged landing [Seconds] in the operated side	1.0 ± 0.5	0.8 ± 0.4
Limb symmetry index [%]	0 ± 35	1 ± 32
Ground reaction peak force at single-legged landing [N/Kg] in the operated side	29 ± 1	32 ± 1
Limb symmetry index [%]	0 ± 7	0 ± 13
Single-legged hop for distance [cm] in the operated side	162 ± 25	150 ± 20
Limb symmetry index [%]	-1 ± 4	1 ± 16

Among the variables, "knee isokinetic extension work at 180°/sec" was the single variable significantly different between the groups, $p < 0.05$

Correlation coefficients *r* between patient demographics and subjective outcomes

Patient/ meniscus variables	PROMs
Women vs. Men	**IKDC-subjective** (85±8 vs. 92±6, *p*<0.01); **KOOS-Sports** (68±15 vs. 82±17, *p*=0.02)
Delay injury-surgery (tear chronicity)	**Inverse correlations with KOOS-**Pain, ADL, Sports, QOL (*r*=-0.3, *p*<0.04)
Tegner level at pre-injury	**Highly correlated** with follow-up Tegner and Marx scores (*r*=0.5, *p*<0.01)
Marx score at pre-injury	**Highly correlated** with follow-up Tegner and Marx scores (*r*=0.5, *p*<0.01)
Age at operation	*p* = NS (not correlated with follow-up PROMs)
Smoking status	*p* = NS (not correlated with follow-up PROMs)
Tear length (number of sutures)	*p* = NS (not correlated with follow-up PROMs)

Correlation coefficients

Thus, for optimal outcomes:

- ***Men* and *active populations* can expect higher PROMs**
- ***Repair* should be performed *as early as possible* to achieve higher PROMs**
- ***Age, smoking, and tear length were not "bad factors "at this point of the study"***

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Correlation coefficients *r* between subjective outcomes and objective biomechanical measures
in the patients with isolated meniscus repair (n.=20)

Subjective outcome Biomechanical variable	Tegner [M limb; SI]	IKDC [M limb; SI]	KOOS-Sports [M limb; SI]	KOOS-ADL [M limb; SI]	KOOS-Symp [M limb; SI]
Knee peak extension torque at 60°/sec	*r*= 0.0; *r*= -0.2	*r*= 0.2; *r*= -0.2	*r*= 0.1; *r*= -0.2	*r*= 0.1; *r*= -0.2	*r*= 0.1; *r*= -0.2
Knee peak extension torque at 180°/sec	*r*= 0.0; *r*= -0.2	*r*= 0.2; *r*= -0.2	*r*= 0.1; *r*= -0.2	*r*= 0.2; *r*= -0.2	*r*= 0.1; *r*= -0.2
Knee peak flexion torque at 60°/sec	*r*= 0.3; *r*= -0.3	*r*= 0.3; *r*= -0.2	*r*= 0.3; *r*= -0.3	*r*= 0.3; *r*= -0.2	*r*= 0.3; *r*= -0.3
Knee peak flexion torque at 180°/sec	*r*= -0.3; *r*= -0.3	*r*= -0.3; *r*= -0.3	*r*= -0.3; *r*= -0.3	*r*= -0.3; *r*= -0.3	*r*= -0.3; *r*= -0.3
Knee extension work at 60°/sec	*r*= 0.0; ***r*= -0.5**	*r*= 0.2; ***r*= -0.5**	*r*= 0.0; ***r*= -0.5**	*r*= 0.2; ***r*= -0.5**	*r*= 0.0; ***r*= -0.5**
Knee extension work at 180°/sec	*r*= 0.1; *r*= -0.4	*r*= 0.2; *r*= -0.3	*r*= 0.1; *r*= -0.3	*r*= 0.2; *r*= -0.3	*r*= 0.1; *r*= -0.3
Knee flexion work at 60°/sec	*r*= 0.2; *r*= -0.2	*r*= 0.3; *r*= -0.2	*r*= 0.2; *r*= -0.2	*r*= 0.3; *r*= -0.2	*r*= 0.2; *r*= -0.2
Knee flexion work at 180°/sec	*r*= 0.1; *r*= 0.1	*r*= 0.3; *r*= 0.1	*r*= 0.2; *r*= 0.2	*r*= 0.3; *r*= 0.2	*r*= 0.2; *r*= 0.2
Time to stability at single-legged land.	*r*= 0.0; *r*= 0.0	*r*= 0.0; *r*= 0.0	*r*= 0.0; *r*= 0.1	*r*= 0.0; *r*= 0.1	*r*= -0.1; *r*= 0.1
Ground reaction peak force	*r*= 0.3; *r*= 0.0	*r*= 0.3; *r*= 0.2	*r*= 0.4; *r*= 0.0	*r*= 0.2; *r*= 0.1	*r*= 0.4; *r*= 0.0
Single-legged hop for distance	*r*= 0.0; *r*= 0.1	*r*= 0.1; *r*= 0.0	*r*= 0.0; *r*= 0.0	*r*= 0.0; *r*= 0.0	*r*= 0.0; *r*= 0.0

Correlation coefficients

M limb = the value in the operated meniscus limb
SI = Symmetry index value

Significant correlations ($p < 0.05$) are bald and encircled

Conclusions

- Gold-standard inside-out repair of long extensive meniscus tears results not only in subjective perceptions of healthy knee in around 85-90% of the operated cases, but also in good-excellent restoration of objectively measured functional parameters of strength and stability, as reflected by the symmetry indices.

- Among the biomechanical variables, “knee isokinetic extension work [Joule/Kg]” seems the most reliable objective predictor to indicate the objective restoration of knee function in conjunction with maintaining sports activities, and should therefore receive specific attention during rehabilitation programs.

- Concerns related to tear chronicity, meniscus laterality, isolated repair versus concomitant ligament surgery, or patient age should be minimized in the decision-making process.

- At the completion of the follow-up in this clinical-biomechanical research within the next two years, decision-making algorithms for optimizing meniscus repair surgery will be elaborated.

- Hetsroni I, et al. Inside-out repair of extensive meniscal tears using posteromedial and posterolateral neurovascular protective windows. *Arth. Tech.* 2021