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ARTHROSCOPY AND SPORTS MEDICINE

Traumatic and degenerative cartilage lesions: arthroscopic differentiation using near-infrared spectroscopy (NIRS)

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Abstract
Introduction Cartilage lesions or defects are the most common finding during knee arthroscopy. During arthroscopy, it is often difficult to differentiate between degenerative and traumatic cartilage lesions. The study aimed to determine the impact of near-infrared spectroscopy (NIRS) on the distinction between traumatic and degenerative cartilage lesions in the medial femoral condyle (MFC). It was hypothesized that NIRS as able to distinguish between traumatic and degenerative cartilage lesions.
Materials and methods Arthroscopic evaluation was performed in six patients who had undergone anterior cruciate ligament (ACL) reconstruction and in six patients who had undergone high tibial osteotomy (HTO). In both groups, a grade III cartilage lesion was present within the MFC. NIRS evaluation was performed with a special probe (arthrospec-one, Arthrospec GmbH, Jena, Germany). NIRS measurements produced semi-quantitative values ranging from 0 (heavily degenerated cartilage) to 100 (completely intact cartilage).
Results The mean near-infrared-light absorption within the traumatic lesions in the MFC of the ACL group was 71.5 (range 61–80). In the HTO patients, this value was significantly ($p < 0.001$) lower at 31.7 (range 31–33). The margin of the MFC outside the lesion in the ACL group had the same adsorption as the lesion ($p = 0.549$).
Conclusion After an injury, cartilage has a normal or nearly normal absorbance on near-infrared-light. Thus, it is possible to distinguish intraoperatively between traumatic and degenerative lesions. In addition, our results demonstrate that evaluating cartilage with NIRS is a dependable method for improving the diagnosis of significant chondral lesions.

Keywords Knee · Cartilage · Arthroscopy · NIRS

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Introduction

Cartilage lesions or defects are the most common finding during knee arthroscopy [1, 8, 12]. These lesions are largely a function of general degeneration within the joint and occur in the initial stage of osteoarthritis. Degenerative cartilage lesions do not have any capacity to heal. Cartilage surgery can be used in special cases.

Another pathophysiological entity is traumatic cartilage lesions or defects, which are associated with major knee injuries. About 15–20 % of anterior cruciate ligament (ACL) lesions are associated with deep cartilage lesions [9, 11, 14, 22]. These lesions result from massive shear forces within the joint surface and most often affect the medial femoral condyle or patella. In comparison to degenerative cartilage lesions, these traumatic lesions have a good prognosis and often heal spontaneously [20, 23]. Nakamura et al. [21] described a significant natural repair response in ACL patients who had deep lesions within the medial condyle. Such lesions seldom require any invasive treatment.

During arthroscopy, it is often difficult to differentiate between degenerative and traumatic cartilage lesions.

Previous experiments [19, 26], and clinical studies [13, 24, 25] have demonstrated the suitability of near-infrared light spectroscopy (NIRS) for diagnosing chondral degeneration.

We hypothesized that NIRS would be able to differentiate between cartilage lesions with a trauma history and (degenerative) cartilage lesions without a trauma history during knee arthroscopy. In traumatic lesions degenerative processes should be absent and the apparent cartilage lesion should demonstrate normal NIRS values.

Methods

Patients

From a retrospective, consecutive series of patients who had undergone ACL reconstructions, a total of six patients were selected with circumscriptive traumatic chondral lesions (stellate-type relative to the linear crack) within the MFC mean bearing zone (Fig. 1). The patients from the ACL group (four males and two females) had suffered from a knee injury within the last 3 months. No patient from this group had any knee problems prior to this injury. The control group (HTO) was composed of patients (three males and three females) who had undergone HTO for medial knee osteoarthritis within the same time interval. Patients from the control group had grade III cartilage lesion within the MFC mean bearing zone (Fig. 2). Patients in the ACL group had normal standard radiographs whereas all patients in the HTO group had slight varus osteoarthritis (Kellgren-Lawrence [17]) grade I.

Fig. 1 Traumatic cartilage lesion: this 30-year-old woman suffered from an ACL injury while playing handball 6 weeks before arthroscopy. During arthroscopy, a linear-crack lesion within the mbz of the MFC was detected. NIRS values were as follows: MFC_mbz 81, MFC_margin 83, TM_mbz 76, and TM-margin 75. The relative high values on NIRS suggest a traumatic etiology for this cartilage lesion

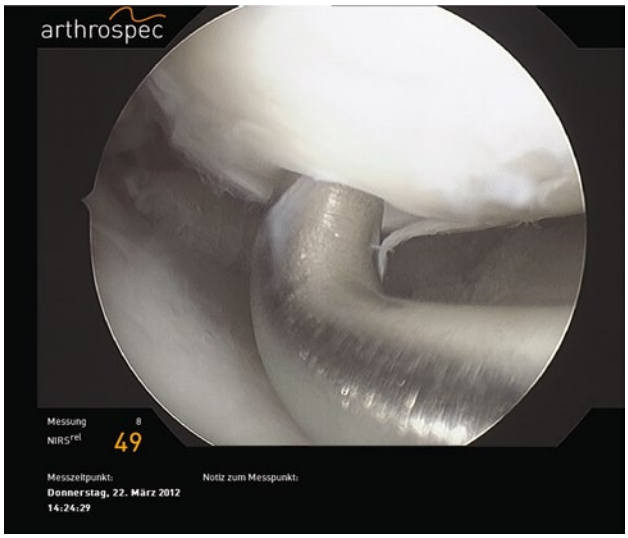

Fig. 2 Degenerative cartilage lesion: this 55-year-old woman had undergone arthroscopy and concomitant HTO (osteoarthritis Kellgren-Lawrence grade I). NIRS value within the mbz of MFC was 49. The relatively low NIRS values suggest a degenerative cartilage lesion

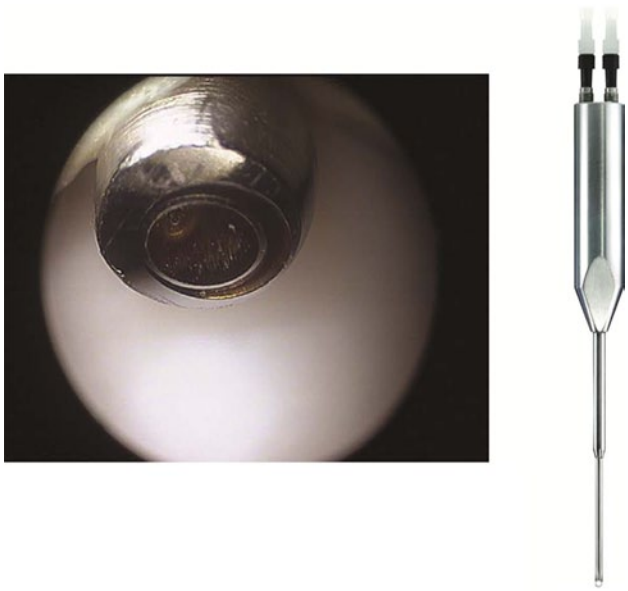

Fig. 3 NIRS probe: the probe is designed in the form and size like a normal arthroscopic hook. The glass fibers pass the top of the instrument (arthrospec 1, arthrospec gmbh Jena, Germany)

Table 1 Distribution of cartilage lesions (ICRS-grade)

ICRS-grade	HTO	ACL
Patella_medial		
0	0	4
I	2	2
II	2	0
III	2	0
Patella_central		
0	0	4
I	0	2
II	3	0
III	3	0
Patella_lateral		
0	0	1
I	2	3
II	2	2
III	2	0
Trochlea_medial		
0	1	3
I	0	3
II	4	0
III	1	0
Trochlea_central		
0	1	3
I	1	2
II	1	0
III	3	1
Trochlea_lateral		
0	1	3
I	1	3
II	3	0
III	1	0
MFC_mbz		
III	6	6
MFC_margin		
0	0	6
I	1	0
II	5	0
TM_mbz		
0	0	2
I	0	4
III	4	0
IV	2	0
TM-margin		
0	0	2
I	0	4
II		
III	2	0
IV	4	0
LFC_mbz		
0	1	5
I	3	1
II	2	0
III		
LFC_margin		
0	1	5
I	2	1
II	3	0
III		
TL_mbz		
0	0	4
I	0	2
II	4	0
III	2	0
TL_margin		
0	1	5
I	2	1
II	3	0
III		

The mean age of the patients in the ACL group was 39.1 years (95 % CI 31.8–47.6 years). The patients in the HTO group were 45.1 (95 % CI 32.6–57.8) years old ($p = 0.341$).

Arthroscopy and NIRS

All arthroscopies were performed under general anesthesia, and a tourniquet was always used. Only one well-experienced surgeon (>10,000 knee arthroscopies) performed the operations. In every patient, the joint surfaces were systematically evaluated at defined points. The patella was investigated at the medial, central, and lateral thirds (Patella_medial, Patella_central and Patella_lateral, respectively). The same inspection was performed within the trochlea: medial, central (groove), and lateral (Trochlea_medial, Trochlea_central and Trochlea_lateral, respectively). Both the medial femoral condyle (MFC) and the lateral femoral condyle (LFC) were investigated within the mean bearing zone (mbz) as well as within the margin of the mean bearing zone. The same was done within the medial (TM) and lateral (LT) tibia.

All regions of interest were evaluated using a special probe (arthrospec-one, Arthrospec GmbH, Jena, Germany), Fig. 3. The probe contains glass fibers. During the measurements, a NIR light is applied to the hyaline cartilage

Table 2 Results of NIRS measurements within the chondral areas

	Mean	SD	SE	95 % confidence interval for mean		Minimum	Maximum	*p*
				Lower bound	Upper bound			
Patella_medial								
HTO	43.2	8.3	4.1	29.9	56.6	36	51	<0.001
ACL	72.6	5.6	2.3	72.6	84.3	74	88	
Patella_central								
HTO	45.0	14.7	7.3	21.6	68.4	30	65	<0.001
ACL	81.0	7.4	3.0	73.2	88.8	72	89	
Patella_lateral								
HTO	47.7	13.8	6.7	26.5	69.0	32	62	<0.001
ACL	77.5	4.7	1.9	72.5	82.5	73	85	
Trochlea_medial								
HTO	47.2	9.9	4.9	73.3	89.4	33	56	<0.001
ACL	81.3	7.7	3.1	73.3	89.4	74	94	
Trochlea_central								
HTO	39.2	6.2	3.1	29.3	492	30	43	0.002
ACL	76.5	5.1	12.1	63.4	89.5	63	96	
Trochlea_lateral								
HTO	55.1	14.9	1.7	31.3	78.7	40	34	0.002
ACL	70.3	8.5	3.5	70.4	88.3	72	94	
MFC_mbz								
HTO	31.7	0.9	0.5	30.3	33.3	31	33	<0.001
ACL	71.5	6.2	2.5	65.4	77.9	61	80	
MFC_margin								
HTO	59.2	22.1	11.0	14.1	84.4	26	71	0.019
ACL	71.5	4.1	1.7	67.1	75.9	66	77	
TM_mbz								
HTO	39.5	11.6	5.8	20.9	58.1	27	55	<0.001
ACL	84.5	9.3	3.8	74.7	94.3	71	96	
TM_margin								
HTO	49.2	17.3	8.6	21.6	76.8	30	68	<0.001
ACL	86.1	10.4	4.2	75.2	97.1	71	96	
LFC_mbz								
HTO	67.5	4.6	2.3	60.1	74.9	63	72	0.001
ACL	91.8	10.0	4.1	81.3	98.2	73	100	
LFC_margin								
HTO	55.8	13.8	6.9	33.7	77.7	42	70	0.005
ACL	87.3	11.8	4.8	74.8	98.2	71	100	
TL_mbz								
HTO	46.0	5.8	11.7	27.4	64.6	30	58	<0.001
ACL	83.0	9.2	3.8	73.3	92.7	71	97	
TL_margin								
HTO	60.2	6.2	3.1	50.2	70.3	65	14	<0.001
ACL	86.3	6.6	2.7	79.4	93.3	74	94	

layer. After light absorption by the cartilage, it is reflected back to the device. Previous work has shown that normal cartilage and degenerated cartilage have different optical (adsorption) properties [3, 6, 7, 16, 18]. The use of NIRS technology for the evaluating cartilage lesions has been described extensive in previous publications. Special software in the device calculates this difference and produces relative values for "cartilage quality". This value ranges

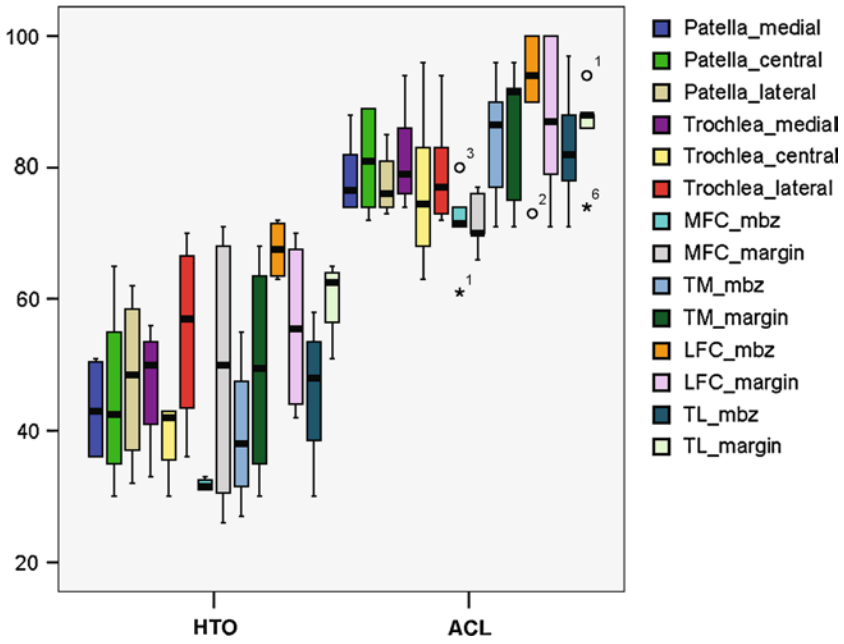

Fig. 4 Results of NIRS measurements in all joint compartments

from 0 (severe chondral damage) to 100 (healthy cartilage). The results are available in real time.

All lesions were classified according to the ICRS score [5].

Evaluation and statistics

The study nurse immediately registered all results in an Excel table. Statistical calculations (ANOVA) for the comparison of means were performed using SPSS (version 20.0, SPSS Inc., Chicago, IL, USA).

Results

The frequency of cartilage lesions (ICRS) for both groups is listed in Table 1. The frequency of deep cartilage lesions in terms of complete cartilage defects was higher in the HTO group. Whereas ACL patients only had severe lesions within the MFC, HTO patients suffering from deep chondral damage in all other compartments.

As shown in Table 2 and Fig. 4, the HTO patients had a significantly higher grade of cartilage degeneration than did the ACL patients. The mean NIRS absorption in the traumatic lesions in the MFC of the ACL group was 71.5 (range 61–80). In the HTO patients, this value was significantly ($p < 0.001$) lower at 31.7 (range 31–33).

The margin of the MFC outside the lesion in the ACL groups had the same adsorption as the lesion ($p = 0.549$). In contrast, the lesion margin within the MFC of the HTO patients tended to be the cartilage of higher quality ($p = 0.010$).

Discussion

This study was undertaken to evaluate the impact of intraoperative NIRS to differentiate between traumatic and degenerative cartilage lesions.

We hypothesized that NIRS would be able to differentiate between traumatic and degenerative cartilage lesions during knee arthroscopy. In traumatic lesions degenerative processes should be absent and the apparent cartilage lesion should demonstrate normal NIRS values. We confirmed our hypothesis. Cartilage after an injury has a normal or nearly normal absorbance for NIR. Thus, it is possible to distinguish intraoperatively between traumatic and degenerative lesions.

The arthroscopic grading of cartilage lesions can be difficult in some cases. The inter-observer reliability is relatively poor [2, 4, 15]. Furthermore, distinguishing between traumatic and degenerative lesions can be impossible. Nevertheless, correct classification of the lesions can be very important. Relative to other methods that rely on biomechanical measurements, NIRS is a much more practical procedure for assessing these lesions. Palpation of the regions of interest with the probe is possible in every region of the knee. Values are given in real time, requiring about 1–2 s per measurement. This real-time measurement is the main difference between NIRS and other biomechanical methods capable of objectifying cartilage lesions [10, 27].

Furthermore, NIRS is able to provide information on the margins of the defects. In our patients, the margins of the main degenerative defects also demonstrated significant pathological values. Often, other regions of the knee were

also involved (Fig. 3). In contrast, all cartilage surfaces in the injured knees demonstrated normal NIRS values.

A limitation associated with the present study is the retrospective study design, a preliminary study. All patients were recruited from a consecutive series from our clinic. Currently, we are not able to give concrete information about the consequences from our measurements for the prognosis of ACL-related or other cartilage lesions. Here, further investigations are urgently needed for understanding of the NIRS-measurement-values.

Conclusion

After an injury, cartilage has a normal or nearly normal absorbance for NIR. Thus, it is possible to distinguish intraoperatively between traumatic and degenerative lesions.

Furthermore, our results demonstrate that NIRS evaluation of cartilage is a dependable method to improve the diagnosis of significant chondral lesions.

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