ORIGINAL ARTICLE

Initial outcomes of anatomical anterior cruciate ligament reconstruction with PEEK CF interference screws in people practising extreme forms of physical activity – mental aspects

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

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Abstract

Background & Study Aim: Anterior cruciate ligament (ACL) is one, if not the most important, ligament in the knee joint. An ACL injury most commonly occurs via a non-contact injury mechanism. Knee joint injuries are also the most common types of serious injuries in judo including ACL injury during e.g. *uchi mata* throw. The aim of the article is the initial results with the usage of polyether ether ketone carbon fibres (PEEK CF) implants in anatomical ACL reconstruction using semitendinosus and gracilis grafts.

Material & Methods: Among 50 patients we selected 27 men practicing extreme forms of physical activity – EFPA (first criterion for inclusion): 12 games, team sport athletes (7 football, 4 handball, 1 volleyball); 10 combat sports athletes (5 judo, 3 kick boxing, 2 thai boxing); 2 athletics; 3 neo-gladiators (MMA). All were operated on between March 2013 and September 2015, due to ACL injury (second criterion for inclusion). The control group consisted of 23 non professional athletes (also patients). The standard anatomical ACL reconstruction technique with semitendinosus and gracilis tendons graft were used in all patients. PEEK CF screws were used to secure the graft in the tibial tunnel and femoral tunnels.

Results: Patients were evaluated using the Lysholm Questionnaire and Tegner activity score after 12 months post-surgery. Good and excellent results were observed. All of the athletes, upon which the procedures were performed, returned to their sporting activities.

Conclusions: The use of PEEK CF material in ACL reconstruction looks promising. Further study and follow up is necessary. Proper education of the treatment of the ACL injury to the sport professionals may result with calming the fear of re-injury that is very common among patients.

Key words: athletic • combat sports • injury • neogladiators • team sports

Conflict of interest: The authors of this study declare that they have no conflicts of interest

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Provenance & peer review: Not commissioned; externally peer reviewed

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Introduction

The anterior cruciate ligament (ACL) is one, if not the most important, ligament in the knee joint. The ACL injury is relatively common in professional athletes due to extreme stress put on the knee joint during training routine. This common injury results in approximately 100,000 ACL reconstructions performed per year in the United States [1-3]. An ACL injury most commonly occurs via a non-contact injury mechanism as a result of: planting and cutting, landing on an extended knee, one-step stop landing with the knee hyperextended, or pivoting and sudden deceleration. Knee joint injuries are also the most common types of serious injuries in judo including ACL injury during e.g. *uchi mata* throw [4].

The patient typically reports a "pop" during the event, immediate pain, limited weight-bearing ability, and progressive knee swelling. An ACL rupture can be diagnosed through history and physical examination but is confirmed through magnetic resonance imaging (MRI).

The treatment for an ACL tear is evaluated on an individual patient basis, as surgery is not an obligatory treatment for an ACL tear. Each individual's activity goals, lifestyle choices, and occupational or educational demands are factors to be taken into consideration when arriving at a treatment plan. The main goal is to reach the optimal function level of the patient without risking further damage [5]. However, for an athlete to return to play and prevent further damage to their knee, ACL reconstruction surgery is typically recommended. ACL reconstruction combined with appropriate rehabilitation protocol provides the young male patients an opportunity of return to the pre-injury sport and recreational activities [6].

The goal of ACL reconstruction should be to closely restore the native anatomy [7]. Anatomic ACL reconstruction is defined as the functional restoration of the ACL to its native dimensions, collagen orientation, and insertion sites [7]. It is felt that surgical reconstruction lessens the risks of development of articular cartilage damage, meniscal tears, which could lead to an accelerated onset of degenerative joint changes [8-13]. These changes are even observed without the presence of associated meniscal injuries [14-15]. Surgery is the preferred treatment for a complete rupture of the ACL in an individual who wishes to return to high-risk activities, defined as: sports, heavy work, and extreme forms of recreational (physical) activity involving pivoting and cutting. ACL reconstruction may also be indicated in the nonathletic patient who reports repeated sudden collapse or "giving out" of the knee in spite of adequate rehabilitation [1, 3].

Many types of implants have been used to secure the grafts in the femoral and tibial tunnels for ACL reconstruction. Most commonly known are: bioabsorbable screws, biocomposite screws, titanium screws and buttons from several manufacturers, e.g., Arthrex, Smith & Nephew, Linvatec and Storz. A new implant system, using interference screws made from PEEK CF polymer, was introduced in 2010 by Parcus Medical (Sarasota, FL, US). This material has promising biomechanical properties. Hence our goal was to examine the use of PEEK screws in ACL reconstruction.

The aim of the article is the initial results with the usage of polyether ether ketone carbon fibres (PEEK CF) implants in anatomical ACL reconstruction using semitendinosus and gracilis grafts.

Material and methods

Participants

Among 50 patients we selected 27 men practising extreme forms of physical activity – EFPA (first criterion for inclusion): 12 games, team sport athletes (7 football, 4 handball, 1 volleyball); 10 combat sports athletes (5 judo, 3 kick boxing, 2 thai boxing); 2 athletics; 3 neo-gladiators (MMA). The control group consisted of 23 non professional athletes (also patients). All were operated on between March 2013 and September 2015, due to ACL injury (second criterion for inclusion).

Ethics Committee was informed about this project – their approval was not necessary. The clinical study were done in accordance with all the medical procedures and the patients gave their permission to be part of the study.

Operative procedure and technique

The implants used for the surgery are approved by the Food and Drug Administration (FDA) for use in humans and the technique of the surgery is well known around the globe. All of the patients presented anterior knee instability proven clinically and radiologically (MRI scan confirmed the diagnosis). All of the ethical guidelines were

ACL – anterior cruciate ligament (ACL) is one of a pair of cruciate ligaments in the human knee. They are also called *cruciform* ligaments as they are arranged in a crossed formation. The anterior cruciate ligament is one of the four main ligaments of the knee, and the ACL provides 85% of the restraining force to anterior tibial displacement at 30 degrees and 90 degrees of knee flexion.

ST-G – semitendinosus (ST) and gracilis (G) tendons harvested from the hamstring. The semitendinosus is an accessory hamstring (the primary hamstrings are left intact), and the gracilis is not a hamstring, but an accessory adductor (the primary adductors are left intact as well). They serve as the graft for the ACL surgery.

PEEK – polyether ether ketone (PEEK) is a colourless organic thermoplastic polymer in the polyaryletherketone (PAEK) family, used in biomaterials implanted in human body.

CF – carbon fibres or carbon fibres (alternatively CF, graphite fibre or graphite fibre) are fibres about 5-10 micrometres in diameter and composed mostly of carbon atoms. They are used in biomaterials implanted in human body.

PLLA – polylactic acid or polylactide (PLA) is a biodegradable and bioactive thermoplastic aliphatic polyester derived from renewable resources, such as corn starch or sugarcane used in biomaterials implanted in human body.

EFPA – "extreme form of physical activity are extreme sports, often classified according to the environment in which they are performed (water, land, air), extreme form of physical recreation as well as gainful activity or voluntary service, and all varieties of physical activity that meet at least one classification criterion of the feature associated either with extreme risk of injury or death, or extreme body burden with high level of effort, or extreme coordination difficulty" [35, p. 19, see also 36]

Team sport – *noun* any sport that is played between two or more teams, e.g. football, tennis or hockey [37].

Uchi mata – thigh throw (inner-thigh throw); leg techniques (sub classification: *ashi waza*) [38].

followed by the investigator (in this case the orthopaedic surgeon – the main author of the publication).

The standard anatomical ACL reconstruction technique with semitendinosus and gracilis tendons graft were used in all patients. PEEK CF screws were used to secure the graft in the tibial tunnel and femoral tunnels.

The patient is placed in supine position and an examination of both knees under anaesthesia is performed. A tourniquet is applied to the operative extremity at a pressure of 300 mm Hg and then the leg is positioned in a leg holder. The non-operative leg is placed in a well-leg holder. With the knee held in 90° of flexion, the portals are made: first the anterolateral portal and then, with the use of a needle to optimize the position, an anteromedial portal. The diagnostic arthroscopy is completed and rupture of the ACL (all patients had an MRI stating total ACL injury) is confirmed intraoperatively (Figure 1). The remnant of the ACL is resected (Figure 2).

The semitendinosus and gracilis graft are harvested from an oblique incision. The femoral tunnel site is marked, a guide wire is placed through the anteromedial portal and a cannulated headed reamer is placed over the guide

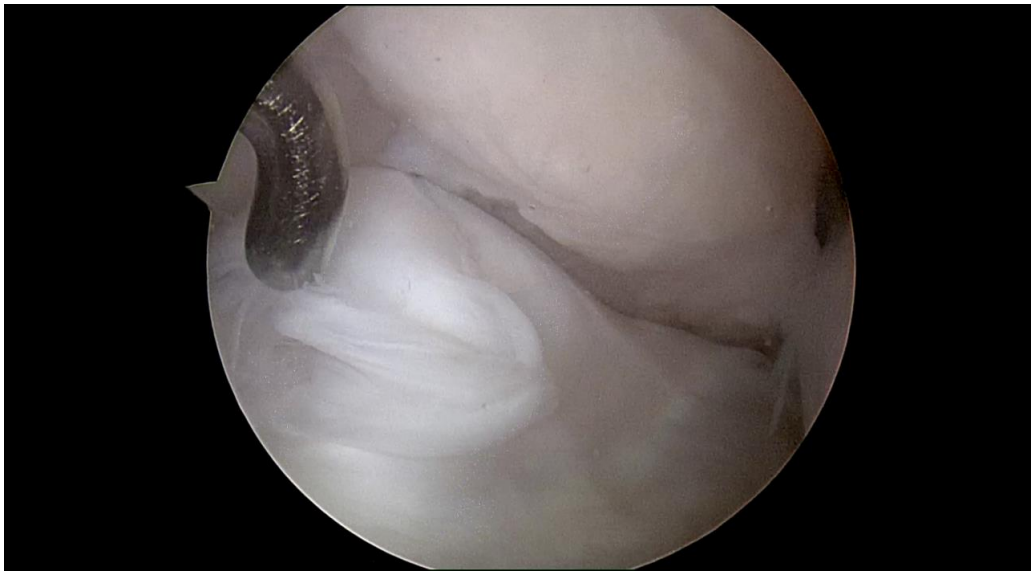

Figure1. An old ACL rupture is seen-the ligament is partially resorbed – the tibial insertion is seen.

Figure 2. The remains of the ACL are shaved, depth of the condyle is measured.

Figure 3. Femoral tunnel was drilled in an anatomical footprint using an 8mm drill, the tunnel is assessed with an arthroscope: the passing suture is seen in the tunnel.

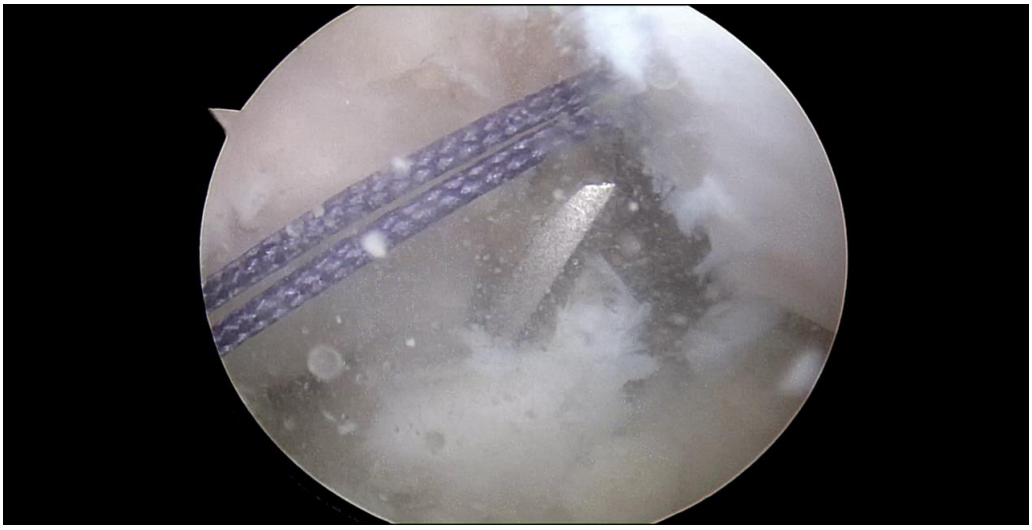

Figure 4. Tibial tunnel is drilled using a 8 mm drill over a guide wire pin (it is seen in the remnant of native ACL) – the drill appears passing through the tibial plateau.

wire and advanced to create the femoral tunnel (Figure 3). A tibial guide is used to place a guide wire for the creation of the tibial tunnel. A cannulated drill is placed over the guide wire and advanced into the joint space to create the tibial tunnel (Figure 4.).

The autograft is placed on the Ethicon suture and passed through the tunnels (Figure 5). On the femoral side PEEK CF screw (Parcus Medical, Sarasota, FL, USA), inserted from inside the joint (both primary and in revision cases) is used (Figure 6).

Femoral screw is assessed in the tunnel to see if it is inserted in the correct position (anterior and inferior to the graft) and if the graft is fit correctly (Figure 7). On the tibial side, a PEEK CF screw is used. The final check of the proper alignment and tension of the graft is established using the probe (Figure 8). Wound is sutured, drainage is put via portals, and sterile bandage is made. PEEK CF screws are supplied in sizes ranging from 7 mm to 12 mm in diameter and 20 mm to 35 mm in length (Figure 9).

All of the surgeries were done in Ursynowskie Centrum Zabiegowe (Warsaw, Poland), by one

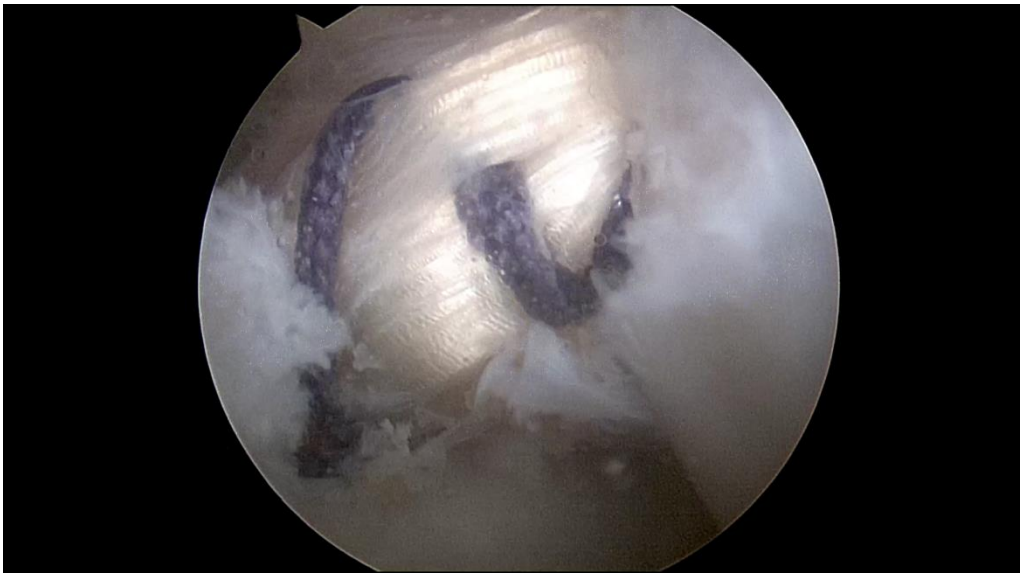

Figure 5. The graft consisting of 2 tendons: semitendinosus and gracilis is passed.

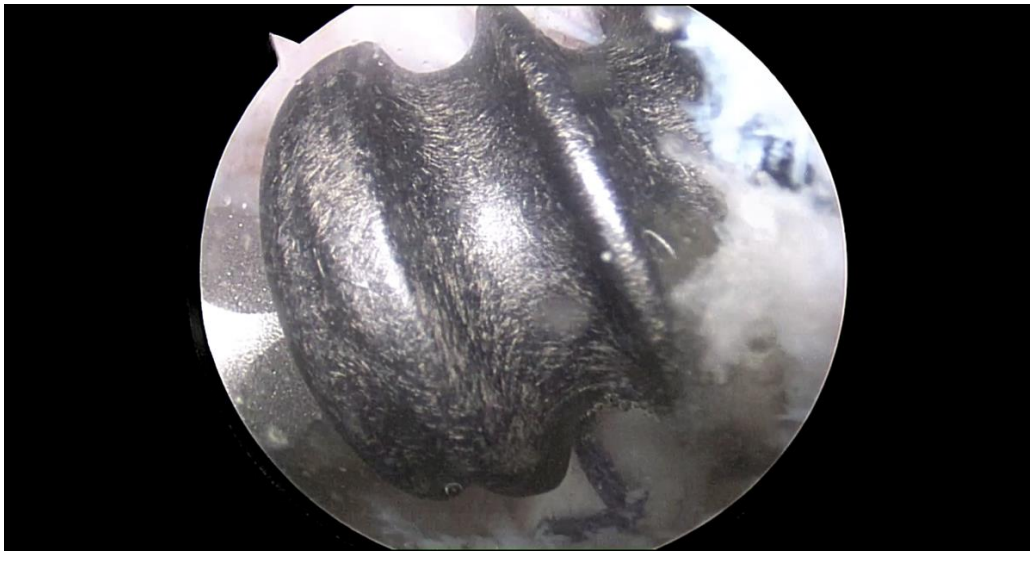

Figure 6. Femoral screw (8 x 30 mm) made of PEEK (polyether ether ketone-colourless organic thermoplastic polymer) with CF (carbon fibre – it gives the screw the characteristic anthracite colour) is inserted using a guide pin and a devoted screwdriver.

surgeon (the author of the publication) who previously had experience using Mitek, Arthrex and Linvatec products for ACL reconstruction.

Moreover 20 of the patients were evaluated using Vicon Motion data were collected using a 10-camera type Vicon system (Vicon, Oxford, UK).

Knee movement were evaluated using Nexus 2 and Polygon 4 software and the results were calculated form 16 markers located on the pelvis, femur, knee, limb and foot of the patient. Angles taken under consideration were: flexion/extension, valgus/varus and rotation of the knee joint. The most improvement were found in rotation: it decreased by an average of 12 degrees. The results are initial, further study is under way with more than 50 patients planned to go full clinical study before and after 12 and 24 months after operation.

Out of 50 ACL reconstructions, 44 were primary and 6 were revision surgeries. Patients were evaluated 12 months post-surgery using the Tegner Activity Scale (Table 1) and Lysholm Scale

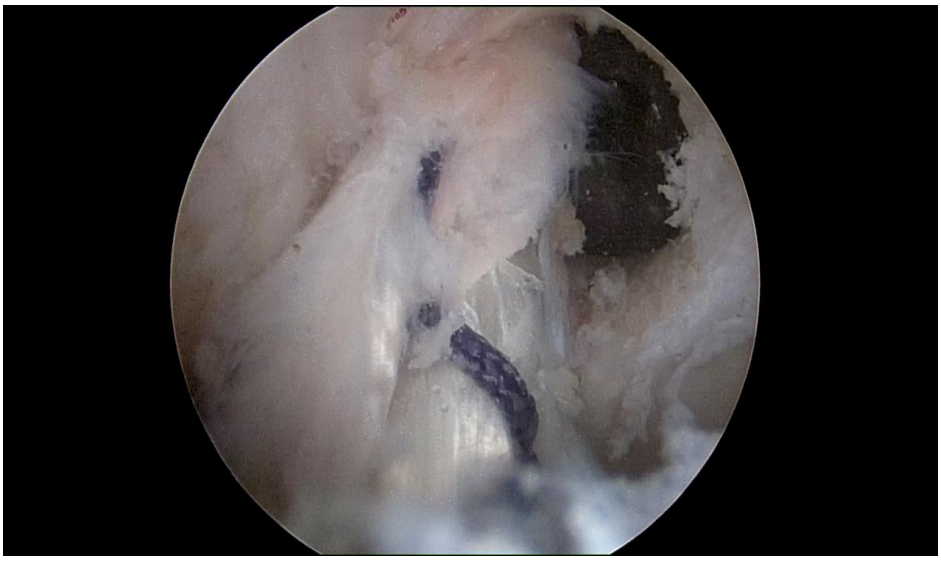

Figure 7. Femoral screw is assessed in the tunnel to see if it is inserted in the correct position (anterior and inferior to the graft) and if the graft is fit correctly.

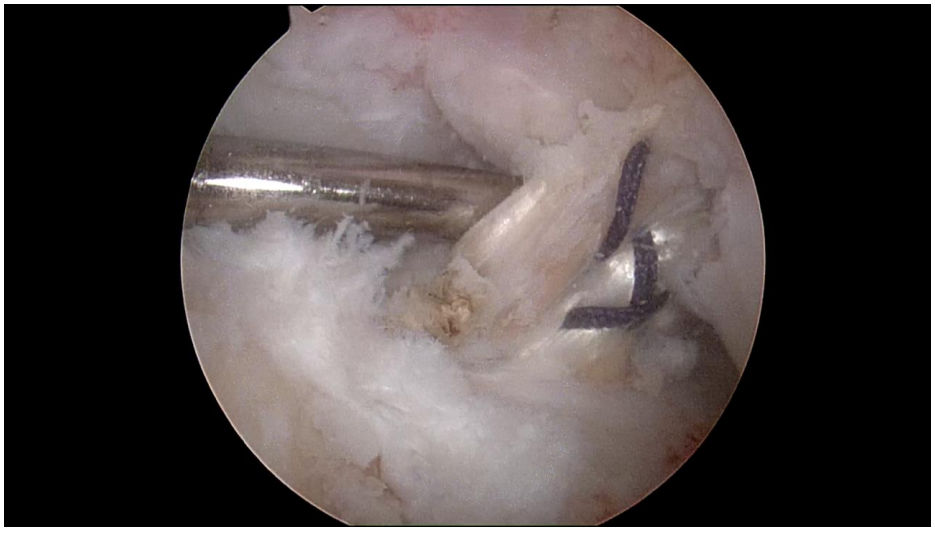

Figure 8. Final check of the proper alignment and tension of the graft is established using the probe.

(Table 2). The Lysholm Knee Scale is an 8-item questionnaire originally designed as an outcome measure for ligament reconstruction [16]. It is widely used across the globe and said to be one of the most known scales for assessing the knee after ligament surgery.

Statistical analysis

Arithmetic means, standard deviations, distribution boundaries of the results (minimal and maximal values) were calculated. In the paper the following tests were applied: non-parametric Wilcoxon's test and Mann-Whitney U test (for comparisons professional athletes from non-professional athletes). Statistically significant difference was assumed for minimum $p<0.05$.

Results

The difference between the results before and after operation were observed in team sports: TAS (5-8) and Lysholm (66-95) – both statistically significant $p<0.05$ (Tables 3, 4). Similar differences were observed in combat sports were statistically significant $p<0.05$ in both TAS (5-8) and Lysholm scale (66-96) (Tables 5-6). In athletics

Figure 9. PEEK-CF screw used to secure the ST-G graft in bone tunnels.

Table 1. Tegner Activity Level Scale (TAS).

Please indicate in the spaces below the HIGHEST level of activity that you participated in BEFORE YOUR INJURY and the highest level you are able to participate in CURRENTLY.
BEFORE INJURY: Level_____ CURRENT: Level_____
Level 10 Competitive sports- soccer, football, rugby (national elite) Level 9 Competitive sports- soccer, football, rugby (lower divisions), ice hockey, wrestling, gymnastics, basketball Level 8 Competitive sports- racquetball or bandy, squash or badminton, track and field athletics (jumping, etc.), down-hill skiing Level 7 Competitive sports- tennis, running, motorcars speedway, handball. Recreational sports- soccer, football, rugby, bandy, ice hockey, basketball, squash, racquetball, running Level 6 Recreational sports- tennis and badminton, handball, racquetball, down-hill skiing, jogging at least 5 times per week Level 5 Work- heavy labour (construction, etc.). Competitive sports- cycling, cross-country skiing. Recreational sports- jogging on uneven ground at least twice weekly Level 4 Work- moderately heavy labour (e.g. truck driving, etc.) Level 3 Work- light labour (nursing, etc.) Level 2 Work- light labour. Walking on uneven ground possible, but impossible to back pack or hike Level 1 Work- sedentary (secretarial, etc.) Level 0 Sick leave or disability pension because of knee problems

Table 2. Lysholm scale questionnaire score.

Section 1 – Limp I have no limp when I walk (5) I have a slight or periodical limp when I walk (3) I have a severe and constant limp when I walk (0)	**Section 5 – Pain** I have no pain in my knee (25) I have intermittent or slight pain in my knee during vigorous activities (20) I have marked pain in my knee during vigorous activities (15) I have marked pain in my knee during or after walking more than 1 mile (10) I have marked pain in my knee during or after walking less than 1 mile (5) I have constant pain in my knee (0)
SECTION 2 – Using support for walking I do not use a cane or crutches (5) I use a cane or crutches with some weight bearing (2) Putting weight on my hurt leg is impossible (0)	**Section 6 – Swelling** I have no swelling in my knee (10) I have swelling in my knee only after vigorous activities (6) I have swelling in my knee after ordinary activities (2) I have swelling constantly in my knee (0)
Section 3 – Locking sensation in the knee I have no locking and no catching sensation in my knee (15) I have catching sensation but no locking sensation in my knee (10) My knee locks occasionally (6) My knee locks frequently (2) My knee feels locked at this moment (0)	**Section 7 – Climbing stairs** I have no problems climbing stairs (10) I have slight problems climbing stairs (6) I can climb stairs only one at a time (2) Climbing stairs is impossible for me (0)
Section 4 – Giving way sensation from the knee My knee gives way (25) My knee rarely gives way, only during athletics or vigorous activity (20) My knee frequently gives way during athletics or other vigorous activities. In turn I am unable to participate in these activities (15) My knee frequently gives way during daily activities (10) My knee often gives way during daily activities (5) My knee gives way every step I take (0)	**Section 8 – Squatting** I have no problems squatting (5) I have slight problems squatting (4) I cannot squat beyond a 90deg. Bend in my knee (1) Squatting is impossible because of my knee (0)
Interpretation A score of 100 means no symptoms or disability. Scores are categorized: Excellent (95–100) Good (84–94) Fair (65–83) Poor (64)	

(Tables 7-8) and neogladiators (Tables 9-10) the differences were similar but they were not statistically significant. The controlled group of non-professional athletes presented the most statistically significant difference ($p<0.001$) both in TAS scale (3-6) and Lysholm scale (67-94) (Tables 11-12). Comparing professionals athletes as a group (n = 24) to recreational sports group the TAS score (mean 2.39) was significantly different $p<0.05$ but no difference were observed using Lysholm scale (comparison was done with U test Mann-Whitney).

Additionally, there were no allergic reactions, redness or irritation of the skin after using the PEEK CF implant. No screws broke during insertion. All of the surgeries were done by one surgeon (the author of the publication) who previously had experience using Mitek, Arthrex and Linvatec products for ACL reconstruction.

Discussion

Authors agrees with signatories of „Czestochowa Declarations 2015: HMA against MMA" that MMA (mixed martial arts) is not eligible for the definition of sport and that all the bloody fights in cages qualifies as neogladiators [17]. Unfortunately in the global media MMA qualifies as a combat sport and this semantic misuse is seen in the some scientific work concerning sport science and sport medicine[18]. We do not question the necessity of proper medical security for such spectacles -as stated e.g. by Pujalte et

Table 3. Results before and after 12 months post operation using Tegner Activity Scale (TAS) by games (team sports) athletes.

Games (team sports) athletes	Tegner Activity Scale (points 1-10)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷ max	
football (n = 7)	**4.7**	-	3÷5	**8.4**	-	7÷9	**3.7***
handball (n = 4)	**4.5**	-	3÷5	**7.5**	-	7÷9	**3.0***
volleyball (n = 1)	**5.0**	-	-	**7.0**	-	-	**2.0**
total (n = 12)	**4.7**	-	3÷5	**8.0**	-	7÷9	**3.3***

*p<0.05 (-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

Table 4. Results before and after 12 months post operation using Lysholm Scale by games athletes.

Games (team sports) athletes	Lysholm Scale (points 0-100)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷ max	
football (n = 7)	**67.8**	-	63÷72	**95.1**	-	94÷100	**27.3**
handball (n = 4)	**63.5**	-	63÷64	**96.5**	-	94÷100	**33.0***
volleyball (n = 1)	**66.0**	-	-	**95.0**	-	95	**29.0**
total (n = 12)	**66.2**	-	63÷72	**95.4**	-	94÷100	**29.2***

*p<0.05 (-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

Table 5. Results before and after 12 months post operation using Tegner Activity Scale (TAS) by combat sports athletes.

Combat sports athletes	Tegner Activity Scale (points 1-10)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷max	
judo (n = 5)	**5**	-	3÷6	**8.6**	-	7÷10	**3.6***
kick boxing (n = 3)	**5**	-	3÷6	**7.3**	-	7÷8	**2.3***
thai boxing (n = 2)	**5**	-	4÷6	**7.5**	-	7÷8	**2.5***
total (n = 10)	**5**	-	3÷6	**8.0**	-	7÷10	**3.0***

*p<0.05 (-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

Table 6. Results before and after 12 months post operation using Lysholm Scale (TAS) by combat sports athletes.

Combat sports athletes	Lysholm Scale (points 0-100)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷max	
judo (n = 5)	**66.4**	-	63÷72	**95.8**	-	94÷100	**29.4***
kick boxing (n = 3)	**67.3**	-	67÷68	**95.7**	-	95÷96	**28.4***
thai boxing (n = 2)	**64.0**	-	64	**97.5**	-	95÷100	**33.5***
total (n = 10)	**66.2**	-	63÷72	**96.1**	-	94÷100	**29.9***

*p<0.05 (-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

Table 7. Results before and after 12 months post operation using Tegner Activity Scale (TAS) by athletes (athletics)

Athletes	Tegner Activity Scale (points 1-10)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷ max	
athletics (n = 2)	**5.5**	-	5÷6	**8.0**	-	7÷9	**2.5**

(-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

Table 8. Results before and after 12 months post operation using Lysholm Scale by athletes (athletics)

Athletes	Lysholm Scale (points 0-100)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷ max	
athletics (n = 2)	**66.5**	-	66÷67	**95.5**	-	95÷96	**29.0**

(-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

Table 9. Results before and after 12 months post operation using Tegner Activity Scale (TAS) by neo-gladiators.

Neo-gladiators	Tegner Activity Scale (points 1-10)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷ max	
n = 3	**4.6**	-	4÷6	**8.0**	-	7÷9	**3.4**

(-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

Table 10. Results before and after 12 months post operation using Lysholm Scale by neo-gladiators.

Neogladiators	Lysholm Scale (points 1-100)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷ max	
n = 3	**65.6**	-	63÷68	**95.6**	-	94÷99	**30.0**

(-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

Table 11. Results before and after 12 months post operation using Tegner Activity Scale (TAS) by non-professional athletes.

Non-professional athletes	Tegner Activity Scale (points 1-10)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷ max	
n = 23	**3.04**	0.47	2÷4	**5.61**	0.94	4÷7	**2.60****

**p<0.01 (-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

Table 12. Results before and after 12 months post operation using Lysholm Scale by non-professional athletes

Non -professional athletes	Lysholm Scale (points 0-100)						Difference
	preoperative			postoperative			
	mean	SD	min ÷ max	mean	SD	min ÷ max	
n = 23	**67.04**	3.62	59÷72	**94.26**	6.33	80÷100	**27.22****

**p<0.01 (-) not available to obtain standard deviation due to inability to assess variables dispersion compatibility with normal variables

al. [18]. Naming MMA as a sport is not rational not only in a semantic way but also in the way of ethics and aesthetics. The legal status of MMA is also fragile as far as sport is concerned. That is why in our work we qualify those patients as neo-gladiators as nobody can be left without proper medical aid.

All of the patients, upon which the procedures were performed, returned to their physical activities. The results were excellent (42 patients), good (7) and fair (1) with the average score of 95.8 (from 65.9 average preoperatively). Tegner Activity Score has adequate test–retest reliability for groups with knee injuries. It is a is a simple freely available measure of activity level that spans work, sporting, and recreational (sport for all) activities. The TAS was originally intended and developed for patients with ACL injury as an adjunct to the Lysholm scale, not as a stand-alone measure. The TAS was significantly improved from 5 (preoperative, range 3–6) to 8 (range 7–10) at l2 months follow-up.

ACL injury is one of the most common injuries in sports medicine. ST-G autograft is the choice for most cases. ACL graft fixation methods have improved significantly, over the past decade. Currently, many methods of fixation are available, including suture-post constructs, staples, soft-tissue washers, buttons, pins, and interference screws [19].

Metal interference screws were first described in ACL reconstruction surgery and bioabsorbable interference screws were developed to overcome some weak points related to their ferromagnetic quality and the difficulty in removal during revision surgery [20]. However, the use of this type of screws does carry some disadvantages, such as greater chance to break during surgery and a possible inflammatory response leading to knee effusion. Knee joint effusion is more common after ACL reconstruction with bioabsorbable interference screw fixation than with metallic interference screw fixation [21] Bioabsorbable poly-L-lactic acid was first used in orthopaedic surgery by Nakamura et al. [22] in 1988 and Rozema et al. [23].

In 1995, Barber et al. [24] published work relating to bioabsorbable implants in ACL reconstructive surgery. Since then, the development and commercial release of bioabsorbable implants in ACL reconstructive surgery have multiplied at the expense of metallic implants [25-28]. PEEK CF is not a novel implant material. Since its introduction to the market in April 1998, PEEK-OPTIMA™ has gained increasing acceptance as a high performance implant material. Significant advantages over metals include: the elimination of imaging artefacts, the ability to view tissue/bone growth and repair using x-rays, which can often be obscured with metal implants and, more generally in this and other applications, the avoidance of allergic tissue reaction to metallic ions.

PEEK-OPTIMA™ is a polyaromatic semicrystalline thermoplastic (typically, 30% to 35% crystallinity) with a melting temperature of ~343°C, a crystallisation peak of ~160°C and a glass transition temperature of ~145°C. It can be readily melt processed by injection moulding and extrusion using conventional methods [29]. With the addition of a filler material, by a process of compounding, which may be in the form of short carbon or glass fibres, the strength of natural unfilled polymer may be increased significantly, in order to cater to greater stress-demanding applications. Stiffness tailoring to bone is also possible, with the judicious selection of fibres or other fillers, at an appropriate concentration. PEEK CF™ displays about the same modulus as bone, with the appropriate selection of fibre type and concentration [29]. PEEK CF is used as a new material for interference screws, used for graft fixation, in ACL reconstruction. It is made of PEEK Optima combined with 30% carbon fibre fill. The mechanical properties of the PEEK CF are closer to cortical bone, especially when compared to titanium or biocomposites. The stiffness is similar to cortical bone (18GPa vs. 15GPa).

By comparison, titanium is 120GPa and PLLA is 2GPa. The stress that would normally be placed on the bone does not concentrate in the implant and therefore bone resorption is less likely to occur. The strength is also the closest to the bone, with PEEK CF at 200MPa and cortical bone at 139GPa. By comparison, Titanium is 790 MPa and PLLA is 50MPa. This data were obtained from the manufacturers, Vitrex and Invibio.

There are no other comparisons of the material to bone available from a neutral source, according to the author's best knowledge.

Although approximately 80% of patients return to some form of activity participation after ACL reconstruction, only 44% return to combat sports [30]. The ability to return to a prior level of sports participation is multifactorial and psychological responses to injury, surgery, and rehabilitation appear to show a role in this phenomenon. Kinesiophobia, or fear of re-injury, is one of the most prevalent psychological factors that may limit a patient's ability to return to pre-injury activity level. The main purpose is to explain to athletes and their trainers the technique of the ACL reconstruction surgery and the implants used in the most simple way. We believe that by explaining all the technical data connected with the surgery to sport professionals (and other EFPA) the possible patient will feel safer and more relaxed about the outcome of the often the necessary surgery. All of the athletes, upon which the procedures were performed, returned to their sporting and physical activities.

Building the trust for aforementioned method of treatment and other new medical technologies is also extremely important due to a fact that many combat sports athletes start training before properly healed or they do not start treatment at all or ignore the effects of over stressing their bodies with physical activity [31, 32]. The inner pressure to sustain training (especially when sport patient is concerned) without proper treatment of the injury can be substitute by immediate decision to undergo operative procedure with a belief that the probability of becoming fully fit for training

is extremely high and the preoperative stress is unnecessary.

This attitude is justified by the result of this work, especially as the results are initial, further study is under way with more than 50 patients planned to go full clinical study before and after 12 and 24 months after operation. A method for the patient with not only ACL injury that in the near future may effectively stimulate behaviour mentioned earlier is the now emerging martial arts bibliotherapy [33, 34].

Conclusions

To the authors best knowledge, there have been no reports regarding the use of PEEK CF implants in ACL reconstruction. Our initial results indicate that PEEK CF provides a promising alternative to the current titanium, bioabsorbale and biocomposite interference screws. Additional evaluation and long term follow up are necessary to further evaluate PEEK CF material for this application.

Highlights

Interference Screws, made from PEEK CF material, are successful, when used for graft fixation in ACL surgery. PEEK CF is a valuable alternative to other graft fixation material in ACL reconstruction. PEEK CF have biomechanical properties similar to cortical bone.

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