RELATÓRIO FINAL DO PÓS-DOUTORADO

DEPARTAMENTO DE ORTOPEDIA E TRAUMATOLOGIA
DISCIPLINA DE MEDICINA ESPORTIVA

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Modalidade: Pós-doutorado

Supervisor: Moises Cohen

Título do projeto: Características clínicas, radiológicas, e funcionais do paciente esqueleticamente imaturo com lesão do ligamento cruzado anterior

Período: 2019-2020

SUMÁRIO

1. RESUMO

Pacientes esqueleticamente imaturos apresentam incidência de lesões do ligamento cruzado anterior (LCA) cada vez maiores. A maior competitividade durante a pratica esportiva, aliada as características anatômicas do joelho infantil favorecem a ocorrência da lesão. Em geral, o tratamento é cirúrgico, com o objetivo de estabilizar o joelho, e minimizar a ocorrência de lesões associadas, como do menisco e da cartilagem.

O processo de recuperação e reabilitação do paciente pediátrico é muito parecido com o paciente adulto. Em geral, após a reconstrução cirúrgica, um período superior a seis meses é necessário para o retorno ao esporte. Diversas técnicas podem ser utilizadas, sempre objetivando minimizar a lesão da fise de crescimento. Porém, diversos estudos relatam maior chance de falha do enxerto ligamentar em pacientes esqueleticamente imaturos. Este numero pode ser até três vezes maior do que no paciente adulto. As técnicas cirúrgicas aplicadas, o comportamento do enxerto ao longo do desenvolvimento musculoesquelético, e até mesmo fatores comportamentais poderiam justificar a maior ocorrência de re-ruptura na população pediátrica. Entretanto, pouco se sabe sobre os fatores de risco para a maior falha da reconstrução do LCA nesta população.

O objetivo primário do projeto é entender por que o comportamento do LCA no paciente esqueleticamente imaturo é diferente do adulto. Avaliar as características anatômicas, funcionais e de imagem que possam justificar este comportamento e, por fim, avaliar as peculiaridades do grupo de pacientes que é optado pelo tratamento cirúrgico e, ainda assim, evolui com falha da reconstrução ligamentar.

2. INTRODUÇÃO

O relatório apresentado refere às atividades desenvolvidas no período de matricula do pós-doutorado (fevereiro de 2019 – março de 2020).

O projeto "Características clínicas, radiológicas, e funcionais do paciente esqueleticamente imaturo com lesão do ligamento cruzado anterior" foi desenvolvido no Programa de Pós-Graduação em Cirurgia Translacional da Escola Paulista de Medicina - Universidade Federal de São Paulo. Faz parte dos estudos das patologias musculoesqueléticas e linha de pesquisa de afecções traumáticas do joelho – sob supervisão do Professor Doutor Moisés Cohen. O objetivo do projeto foi aumentar o conhecimento da lesão do ligamento cruzado anterior do joelho na população pediátrica, resultando em novas publicações, apresentações em congressos, palestras ministradas, projetos de mestrado, e capítulos de livro.

O projeto foi desenvolvido no Centro de Traumatologia do Esporte, da Disciplina de Medicina Esportiva do Departamento de Ortopedia e Traumatologia da Escola Paulista de Medicina - Universidade Federal de São Paulo, durante o Ambulatório do Joelho, às terças-feiras, das 11:00 às 14:00 horas. Neste ambulatório era realizada toda a avaliação clínica e cirúrgica do paciente.

A avaliação de imagem de exames complementares foi realizada pelo Departamento de Diagnóstico por Imagem da Escola Paulista de Medicina - Universidade Federal de São Paulo.

O projeto ainda foi determinante para o mestrado profissional de um aluno (em andamento) no Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo, intitulado "Caracterização radiológica de pacientes esqueleticamente imaturos com lesão do ligamento cruzado anterior".

3. APRESENTAÇÃO CIENTÍFICA DO PROJETO

O público alvo do projeto foram Pacientes esqueleticamente imaturos que evoluíram com a lesão do LCA, e concordaram em participar do estudo de avaliação e acompanhamento clínico.

Os critérios de inclusão foram: pacientes com idade inferior a 16 anos; radiografia do joelho com imagem sugerindo a presença ativa das linhas de crescimento; diagnóstico clínico e de imagem (Ressonância Magnética) de lesão do ligamento cruzado anterior; uso do enxerto de tendões dos músculos flexores-semitendíneo e grácil - para os casos de reconstrução cirúrgica do ligamento. Os critérios de exclusão foram: cirurgias prévias no mesmo joelho; lesões ligamentares associadas no mesmo joelho que necessitaram de intervenção cirúrgica; fraturas da espinha tibial; e o uso de outras opções de enxerto ligamentar, que não os tendões flexores do joelho.

Foram avaliadas as características clínicas (idade biológica, estágio de Tanner, idade óssea, modalidade esportiva praticada, lesões associadas); características do tratamento do paciente (conservador x cirúrgico; técnica cirúrgica, métodos de fixação, tempo de reabilitação, momento do retorno ao esporte); características do exame de imagem (características da linha de crescimento ósseo – fisária - na radiografia do joelho, e caracterização da lesão no exame de Ressonância Magnética - mensuração de linhas e ângulos anatômicos como por exemplo o slope tibial, slope meniscal, e índice do intercôndilo femoral); resultados obtidos da aplicação de questionários funcionais do joelho (escores de Lysholm, IKDC, e Tegner), qualidade de vida (escore de SF-36), e escalas visuais de dor; características específicas da população aonde ocorreu a re-ruptura do LCA (falência do enxerto ligamentar) e suas possíveis causas.

Os principais resultados encontrados são listados abaixo:

3.1. Maioria dos pacientes avaliados eram do sexo masculino;

3.2. Idade média dos pacientes avaliados foi de 13.6 +/- 2.5 anos;

3.3. Seguimento em média de 7.4 +/- 4.5 anos dos pacientes avaliados;

3.4. Maioria dos pacientes caracterizados como estágio de Tanner III e IV;

3.5. 67% das re-rupturas ocorreram após 24 meses; 17 % entre 12-24 meses; 5% entre 6-12 meses; e 11% antes de 6 meses da data da reconstrução primária do ligamento cruzado anterior;

3.6. 77.8 % das re-rupturas ocorreram antes do paciente completar 20 anos de idade;

3.7. O tempo médio de reabilitação até retorno às atividades foi de 7.4 +/- 1.0 meses, variando de 6-9 meses;

3.8. Apenas dois pacientes evoluíram com ruptura do enxerto no período de reabilitação fisioterápica;

3.9. O escore de Tegner médio, quatro semanas após retorno às atividades foi de 7 +/- 0.8 entre os pacientes que evoluíram com o ligamento reconstruído integro;

3.10. O escore de Tegner médio, quatro semanas após retorno às atividades foi de 4.9 +/- 1.3 entre os pacientes que evoluíram com re-ruptura do ligamento;

3.11. Após quatro semanas de retorno às atividades, apenas 5.6 % dos pacientes com re-ruptura alcançaram a pontuação do escore de Tegner que apresentavam antes da lesão primária;

3.12. Após quatro semanas de retorno às atividades, 46.2 % dos pacientes com ligamento integro superaram a pontuação do escore de Tegner que apresentavam antes da lesão primária;

3.13. Após quatro semanas de retorno às atividades, 46.2 % dos pacientes com ligamento integro evoluíram com a mesma pontuação do escore de Tegner que apresentavam antes da lesão primária;

3.14. Após quatro semanas de retorno às atividades, 15.3 % dos pacientes com ligamento integro evoluíram com pontuação do escore de Tegner inferior ao que apresentavam antes da lesão primária;

3.15. O escore de Lysholm foi de 90.6 +/- 6.1 em pacientes submetidos a reconstrução do LCA após retorno ao esporte, e que evoluíram com o enxerto integro no período avaliado;

3.16. O escore de Lysholm foi de 58.8 +/- 6.7 em pacientes submetidos a reconstrução do LCA após retorno ao esporte, e que evoluíram com o re-ruptura do enxerto ligamentar no período avaliado;

3.17. A lesão concomitante mais comum foi a do menisco medial;

3.18. O esporte praticado mais comum foi o futebol (34.6%), seguido pelo basquete e esqui (5.8%). 23 % dos pacientes com lesão do ligamento cruzado anterior não praticavam esporte no momento da rotura;

3.19. A técnica cirúrgica mais realizada foi a reconstrução artroscópica com túnel femoral verticalizado, seguida pela reconstrução anatômica;

3.20. A fixação femoral mais realizada foi com parafuso transverso, seguido por botão cortical, e parafuso de interferência;

3.21. A fixação tibial mais realizada foi com parafuso de interferência, seguido pelo botão cortical;

3.22. O tamanho médio do diâmetro do enxerto de tendão dos músculos flexores foi de 7.6 +/- 0.7 milímetros;

3.23. Pacientes com lesão do ligamento cruzado anterior apresentaram valores superiores do slope meniscal medial que pacientes sem lesão do ligamento cruzado anterior ($p<0.05$);

3.24. Pacientes com lesão do ligamento cruzado anterior apresentaram valores superiores do slope meniscal lateral que pacientes sem lesão do ligamento cruzado anterior ($p<0.05$);

3.25. Pacientes que evoluíram com ruptura do enxerto ligamentar apresentavam maiores valores do slope tibial medial que aqueles com lesão primária do ligamento cruzado anterior ($p<0.05$);

3.26. Pacientes que evoluíram com ruptura do enxerto ligamentar apresentavam maiores valores do slope meniscal medial que aqueles com lesão primária do ligamento cruzado anterior ($p<0.05$).

4. DESCRIÇÃO DAS ATIVIDADES REALIZADAS – ENSINO E PESQUISA

4.1. AULAS MINISTRADAS

4.1.1. Tema: Tratamento do Ligamento Cruzado Anterior no paciente adulto e com fise aberta <1º Curso de Imersão de Cirurgia do Joelho do Instituto Cohen; São Paulo, Brasil – fevereiro de 2019>;

4.1.2. Tema: Caso Clínico: Ligamento Cruzado Anterior no paciente com fise aberta <1º Curso de Imersão de Cirurgia do Joelho do Instituto Cohen; São Paulo, Brasil – fevereiro de 2019>;

4.1.3. Tema: Osteocondrites ao nível do joelho <1º Curso de Imersão de Cirurgia do Joelho do Instituto Cohen; São Paulo, Brasil – fevereiro de 2019>;

4.1.4. Tema: Lesão cruzado anterior em paciente com fise aberta < Reunião Mensal da Sociedade Brasileira de Cirurgia do Joelho; São Paulo, Brasil – março de 2019>;

4.1.5. Tema: Síndrome Patelofemoral < Liga Acadêmica de Traumatologia do Esporte; São Paulo, Brasil – abril de 2019>;

4.1.6. Tema: Articulação Patelofemoral do Joelho < Reunião Clínica do Centro de Traumatologia do Esporte EPM/UNIFESP; São Paulo, Brasil – maio de 2019>;

4.1.7. Tema: ACLR in Open Epiphyses/ RCLA en Epífisis Abiertas < 12th Biennial International Society of Arthroscopy, Knee Surgery & Orthopaedic Sports Medicine Congress; Cancun, México – maio de 2019>;

4.1.8. Tema: Gene Expression of Healing Factors as a predictor to treat Anterior Cruciate Ligament injuries < 12th Biennial International Society of Arthroscopy, Knee Surgery & Orthopaedic Sports Medicine Congress; Cancun, México – maio de 2019>;

4.1.9. Tema: All epiphyseal and Partial Transphyseal ACL reconstruction < International Child and Adolescent Knee Congress; Sheffield, Inglaterra – junho de 2019>;

4.1.10. Tema: What happens to the graft with growth < International Child and Adolescent Knee Congress; Sheffield, Inglaterra – junho de 2019>;

4.1.11. Tema: Interactive Panel Discussion II: ACL Injuries. With: Nev Davies, Peter Fauno, Adrian Wilson, Franck Accadbled, Guido Geutjens, James Fernandes, and Nishith Shah < International Child and Adolescent Knee Congress; Sheffield, Inglaterra – junho de 2019>;

4.1.12. Tema: Revision ACL reconstruction in Children < International Child and Adolescent Knee Congress; Sheffield, Inglaterra – junho de 2019>;

4.1.13. Tema: Patellofemoral session II. Session Chair < International Child and Adolescent Knee Congress; Sheffield, Inglaterra – junho de 2019>;

4.1.14. Tema: Lesões Musculares < V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte; Rio de Janeiro, Brasil – agosto de 2019>;

4.1.15. Tema: Terapia Gênica < V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte; Rio de Janeiro, Brasil – agosto de 2019>;

4.1.16. Tema: ACL in pediatric population < Brazilian – University of Connecticut Symposium; Hartford, Estados Unidos – setembro de 2019>;

4.1.17. Tema: Lesão da Raiz Meniscal < 11ª Jornada Médica do Departamento Médico do Avaí Futebol Clube; Florianópolis, Brasil – novembro de 2020>;

4.1.18. Tema: Lesão Muscular < 11ª Jornada Médica do Departamento Médico do Avaí Futebol Clube; Florianópolis, Brasil – novembro de 2020>;

4.1.19. Tema: Lesão da raiz meniscal < Reunião Clínica do Centro de Traumatologia do Esporte EPM/UNIFESP; São Paulo, Brasil – novembro de 2019>;

4.1.20. Tema: Anterior cruciate ligament re-rupture in pediatric population is related to lower functional scores at return to activity: a prospective,

mid-term follow-up study < 2020 Biennial Meeting Anterior Cruciate Ligament Study Group; Kitzbuhel, Áustria – janeiro de 2020>;

4.1.21. Tema: Fraturas por estresse < Aula de revisão para os residentes do 3º ano do Departamento de Ortopedia e Traumatologia da EPM/UNIFESP; São Paulo, Brasil – fevereiro de 2020>;

4.1.22. Tema: Complicações da Cirurgia do LCA < Curso de Revisão para Residentes especializando em cirurgia do Joelho da SBCJ; São Paulo, Brasil – fevereiro de 2020>;

4.1.23. Tema: Anatomia, exame físico, e patologias do joelho no esporte <Reunião Clínica da Disciplina de Medicina do Esporte da EPM-UNIFESP; São Paulo, Brasil – fevereiro de 2020>.

4.2. PREMIAÇÕES

4.2.1. Prêmio: 1º lugar melhor Tema Livre: Gene Expression of Healing Factors as a predictor to treat Anterior Cruciate Ligament injuries <V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte; Rio de Janeiro, Brasil – agosto de 2019>;

4.2.2. Prêmio: 2º lugar melhor Tema Livre intitulado: Caracterização radiológica de pacientes esqueleticamente imaturos com lesão do ligamento cruzado anterior e meniscal < XXIII Congresso de ortopedia e Traumatologia do Estado do Ceará; Fortaleza, Brasil – agosto de 2019>;

4.2.3. Prêmio: 1º lugar melhor artigo científico de pesquisa clínica publicado no ano de 2019 pela revista Arthroscopy: The Journal of Arthroscopic & Related Surgery, intitulado: The Presence of the Arthroscopic “Floating meniscus”sign as na indicator for surgical intervention in patients with combined anterior cruciate ligament and grade II medial collateral ligament injury < Estados Unidos - dezembro de 2019>

4.3. APRESENTAÇÕES EM CONGRESSO

4.3.1. Apresentação oral. Tema: Treatment and outcomes of lateral collateral ligament injury associated with anterior and posterior cruciate ligament injury at 2-year follow-up < 12th Biennial International Society of Arthroscopy, Knee Surgery & Orthopaedic Sports Medicine Congress; Cancun, México –maio de 2019 >;

4.3.2. Apresentação em pôster eletrônico. Tema: The Use of the Bi-Component Carboxymethylcelulose-Polysaccarid B in the Knee Joint During ACL Reconstruction < 12th Biennial International Society of Arthroscopy, Knee Surgery & Orthopaedic Sports Medicine Congress; Cancun, México – maio de 2019 >;

4.3.3. Apresentação em pôster eletrônico. Tema: Arthroscopic Assessment of meniscal injuries using an anatomical zone classification system < 12th Biennial International Society of Arthroscopy, Knee Surgery & Orthopaedic Sports Medicine Congress; Cancun, México – maio de 2019 >;

4.3.4. Apresentação oral. Tema: A presença do sinal do Menisco Flutuante como indicativo da necessidade de tratamento cirúrgico na lesão combinada do LCA com o LCM grau II < V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte; Rio de Janeiro, Brasil – agosto de 2019 >;

4.3.5. Apresentação oral. Tema: Incidência da cirurgia de revisão do LCA em pacientes pediátricos < V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte; Rio de Janeiro, Brasil – agosto de 2019 >;

4.3.6. Apresentação oral. Tema: Relação entre os valores obtidos de escores funcionais no retorno às atividades após a reconstrução do LCA em pacientes pediátricos que evoluíram com ou sem re-ruptura ligamentar <V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte; Rio de Janeiro, Brasil – agosto de 2019 >;

4.3.7. Apresentação oral. Tema: Comparação Biomecânica das Técnicas de Sutura Vertical e Cruzada, em Fileira Única e Dupla, para o Tratamento da Lesão Meniscal Medial em Alça de Balde <V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte; Rio de Janeiro, Brasil – agosto de 2019 >;

4.3.8. Apresentação em pôster eletrônico. Tema: A substantial to almost perfect agreement between arthroscopic assessment of meniscal injuries and the anatomic meniscal zone classification system proposed by Smigielski– EP01 < V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte; Rio de Janeiro, Brasil – agosto de 2019 >;

4.3.9. Apresentação em pôster eletrônico. Tema: Evaluation and Management of Subchondral Calcium Phosphate Injection Technique to Treat Bone Marrow Lesion – EP34 < V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte; Rio de Janeiro, Brasil – agosto de 2019 >;

4.3.10. Apresentação oral. Tema: Anterior cruciate ligament re-rupture in pediatric population is related to lower functional scores at return to activity: a prospective, mid-term follow-up study < 2020 Biennial Meeting Anterior Cruciate Ligament Study Group; Kitzbuhel, Áustria – janeiro de 2020>.

4.4. PARTICIPAÇÕES EM EVENTOS

4.4.1. Organização e Palestrante: 1º Curso de Imersão de Cirurgia do Joelho do Instituto Cohen. 2019. Brasil;

4.4.2. Palestrante: Reunião Mensal da Sociedade Brasileira de Cirurgia do Joelho. 2019. Brasil;

4.4.3. Palestrante: 12th Biennial International Society of Arthroscopy, Knee Surgery & Orthopaedic Sports Medicine Congress. 2019. México;

4.4.4. Palestrante: 1st International Child and Adolescent Knee Congress. 2019. Inglaterra;

4.4.5. Palestrante: V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte. 2019. Brasil;

4.4.6. Palestrante: University of Connecticut Symposium. 2019. Estados Unidos;

4.4.7. Palestrante: 11ª Jornada Médica do Departamento Médico do Avaí Futebol Clube. 2019. Brasil;

4.4.8. Palestrante: 2020 Biennial Meeting Anterior Cruciate Ligament Study Group. 2020. Áustria.

4.5. PUBLICAÇÕES

4.5.1. Martinelli RVR, Astur DC, Miyashita GK, Novaretti JV, Cohen M, Nicolini AP. The 50 most cited articles in the Brazilian medical literature on knee surgery. Acta Ortop Bras. 2020; 28(1): 44-48.

4.5.2. Astur DC, Angelini FB, Santos MA. Arliani GG, Belangero OS, Cohen M. Uso do ácido hialurônico exógeno no tratamento da condropatia patelar – ensaio clínico randomizado com acompanhamento de seis meses. Rev Bras Ortop. 2019; 54(5): 549-555.

4.5.3. Nakama GY, Kaleka CC, Franciozi CE, Astur DC, Debieux P, Krob JJ, Aman ZS, Kemler BR, Storaci HW, Dornan GJ, Cohen M, LaPrade RF. Biomechanical comparison of vertical mattress and cross-stich suture techniques and single-and-double-row configurations for the treatment of bucket-handle medial meniscal tears. Am J Sports Med. 2019, 47(5): 1194-1202.

4.5.4. Astur DC, Freitas EV, Cabral PB, Morais CC, Pavei BS, Kaleka CC, Debieux P, Cohen M. Evaluation and management of subchondral calcium phosphate injection technique to treat bone marrow lesion. Cartilage. 2019; 10(4): 395-401.

4.5.5. Astur DC, Novaretti JV, Cavalcante ELB, Goes A, Kaleka CC, Debieux P, Krob JJ, Freitas EV, Cohen M. Pediatric anterior cruciate ligament reruptures are related to lower functional scores at the time

of return to activity: a prospective, midterm follow-up study. Orthop J Sports Med. 2019; 7(12): 2325967119888888.

4.5.6. Cabral PB, Astur DC, Freitas EV, Pavei BD, Kaleka CC, Cohen MM. Osteotomias femorais distais com cunha de fechamento medial – estudo retrospectivo. Rev Bras Ortop. 2019; 54(2): 198-201.

4.5.7. Funchal LFZ, Astur DC, Ortiz R, Cohen M. The presence of the arthroscopic "floating meniscus" sign as an indicator for surgical intervention in patients with combined anterior cruciate ligament and grade II medial collateral ligament. Arthroscopy. 2019; 35(3): 930-937.

4.5.8. Amaro JT, Novaretti JV, Astur DC, Cavalcante ALB. Rodrigiues AR, Debieux P, Kaleka CC, Cohen M. Higher axial tibiofemoral rotation and functional outcomes with mobile- bearing compared with fixed-bearing total knee arthroplasty at 1-but not at 2 year follow-up – a randomized controlled trial. J Knee Surg. 2019

4.5.9. Lima FM, Debieux P, Astur DC, Luzo MV, Cohen M, Cardoso FN, Aihara AY, Grimberg A, Fernandes ARC. The development of the anterior cruciate ligament in the paediatric population. Knee Surg Sports Traumat Arthrosc. 2019; 27(10): 3354-3363.

4.5.10. Ramos LA, Zogbi T, Andrade EF, Oliveira GT, Nicolini AP, Krob JJ, Yamashita JL, Cohen M, Astur DC. Treatment and outcomes of lateral collateral ligament injury associated with anterior and posterior cruciate ligament injury at 2-year follow-up. J Orthop. 2019; 16(6): 489-492.

4.5.11. Astur DC, Pires D, Parente T, Debieux P, Kaleka CC, Skaf A, Cohen M. Short term evaluation of the hamstring graft diameter after ACL reconstruction. Muscle Lig Tend Journal. 2019; 9(1) doi: 10.32098/mltj.01.2019.01

4.5.12. Astur DC, Baras FC, Chaim RM, Krob JJ, Arliani GG, Oliveira GT, Cohen M. The efficacy of bi-component carboximethylcellulose-polysaccharide B as a hemostatic and anti-adherent agent at the tibial insertion of the hamstring tendons after reconstruction of the anterior cruciate ligament. Muscle Lig Tend Journal. 2019; 9(1) doi: 10.32098/mltj.01.2019.02

4.6. ACEITOS PARA PUBLICAÇÃO

4.6.1. Nicolini AP, Ejnisman B, Mansur NB, Dreyfuss J, Cohen M, Astur DC. Evaluation of CTX II biomarker in patients with anterior cruciate ligament disruption – pilot study. Rev Bras Ortop. 2020.

4.6.2. Astur DC, Novaretti JV, Gomes ML, Rodrigues AG, Kaleka CC, Cavalcante ELB, Debieux P, Amaro JT, Cohen M. Medial Opening Wedge High Tibial Osteotomy Decreases Medial Meniscal Extrusion and Improves Clinical Outcomes and Return to activity. Orthop J Sports Med. 2020.

4.6.3. Miyahira MKC, Novaretti JV, Astur DC, Kaleka CC, Amaro JT, Cohen M. Lesões condrais maiores tratadas com uso de membrana de colágeno –condrogênese autóloga induzida por matriz – apresentam maior aumento nos escores clínicos. Rev Bras Ortop. 2020.

4.6.4. Nacca DC, Amaro JT, Miyahira MKC, Novaretti JV, Astur DC, Cohen M. Estudo comparativo da função e qualidade de vida de pacientes submetidos à artroplastia total de joelho com plataformas tibiais fixa e móvel. Rev Bras Ortop. 2020.

5. ORIENTAÇÃO E COORIENTAÇÃO DE PROJETOS DE PÓS GRADUAÇÃO DE ALUNOS – UNIFESP

5.1. TESES CONCLUÍDAS

5.1.1. Aluno: Alexandre Pedro Nicolini. Título: Avaliação da degeneração precoce da cartilagem em pacientes com lesão do ligamento cruzado anterior – análise por biomarcador. Nível: Mestrado Profissional. Relação: Orientador. Status: Defendido. Ano: 2019. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.1.2. Aluno: Felipe Bertelli Angelini. Título: Avaliação dos resultados clínicos e de ressonância magnética do uso do ácido hialurônico em pacientes portadores de condropatia patelar dolorosa. Nível: Mestrado Profissional. Relação: Orientador. Status: Defendido. Ano: 2019. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.1.3. Aluno: Daniel Carvalho de Oliveira. Título: Morfologia CAME do quadril em atletas de futebol profissional: existe associação com incidência pélvica reduzida? . Nível: Mestrado Profissional. Relação: Orientador. Status: Defendido. Ano: 2019. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.1.4. Aluno: Renan Moukbel Chaim. Título: O uso do bi-componente carboximetilcelulose-polissacarídeo B na articulação do joelho pós reconstrução do ligamento cruzado anterior. Nível: Mestrado Profissional. Relação: Orientador. Status: Defendido. Ano: 2019. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.1.5. Aluno: Caroline Marques dos Santos Cavalero Cruel Neves. Título: Tomografia computadorizada nas fraturas do tornozelo: modificador de diagnóstico, conduta e planejamento cirúrgico. Nível: Mestrado Profissional. Relação: Orientador. Status: Defendido. Ano: 2019. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.1.6. Aluno: João Victor Novaretti. Título: Efeitos do Transplante de Menisco Lateral na estabilidade e biomecânica do joelho: estudo robótico avaliando das técnicas de fixação com bloco ósseo e apenas com sutura. Nível: Doutorado. Relação: Coorientador. Status: Defendido. Ano: 2019. Programa de Pós-Graduação em Cirurgia Translacional da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.2. TESES EM ANDAMENTO

5.2.1. Aluno: Eduardo Vasconcelos de Freitas. Título: Caracterização radiológica de pacientes esqueleticamente imaturos com lesão do ligamento cruzado anterior . Nível: Mestrado Profissional. Relação: Orientador. Status: Em andamento. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.2.2. Aluno Lorenzo Fagotti. Título: Revisão sistemática dos resultados clínicos da artroplastia total de quadril através da comparação das vias anterior, posterior e lateral. Nível: Mestrado Profissional. Relação: Orientador. Status: Em andamento. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.2.3. Aluno: Lucas Furtado da Fonseca. Título: Caracterização do desempenho motor de tornozelos normais através da avaliação

isocinética. Nível: Mestrado Profissional. Relação: Orientador. Status: Em andamento. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.2.4. Aluno: João Polydoro Rosa. Título: Avaliação do déficit de rotação medial do ombro e protocolo para prevenção do ombro em risco no atleta de crossfit. Nível: Mestrado Profissional. Relação: Orientador. Status: Em andamento. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.2.5. Aluno: Rafael Peloso Reis Ribeiro. Título: Reprodutibilidade da classificação anatômica de Smigielski para roturas meniscais nos estudos de Ressonância Magnética do joelho. Nível: Mestrado Profissional. Relação: Coorientador. Status: Em andamento. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.2.6. Aluno: Manoel da Mota Santos. Título: Uso do selante de fibrina heterólogo na cicatrização da lesão muscular. Nível: Mestrado Profissional. Relação: Coorientador. Status: Em andamento. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

5.2.7. Aluno: Elton Luiz Batista Cavalcante. Título: Uso do selante de fibrina heterólogo na cicatrização do menisco. Nível: Mestrado Profissional. Relação: Coorientador. Status: Em andamento. Programa de Pós-Graduação em Ciências da Saúde Aplicada ao esporte e à Atividade Física da Escola Paulista de Medicina - Universidade Federal de São Paulo.

6. PARTICIPAÇÃO EM BANCAS (UNIFESP)

6.1. Tipo: Mestrado Profissional. Aluno: Rafael Mohriak de Azevedo. 2019

6.2. Tipo: Mestrado Profissional. Aluno: Leandro Masini Ribeiro. 2019

6.3. Tipo: Mestrado Profissional. Aluno: André Vitor Kerber Cavalcante Lemos . 2019

6.4. Tipo: Mestrado Profissional. Aluno: Vitor Luís Pereira. 2019

7. REVISOR DE PERIÓDICOS

7.1. American Journal of Sports Medicine (FI: 6.057)

7.2. International Orthopaedics (FI: 1.58)

7.3. The Knee Journal (FI: 1.762)

7.4. Clinics Journal (FI: 0.37)

7.5. Orthopaedic Journal of Sports Medicine (Open Acess)

7.6. The Lancet Reumathology (FI: ainda não calculado)

7.7. BMC Musculoskeletal Disorders Journal (FI:1.52)

7.8. International Journal of Orthopaedics Surgery and Research (Open Acess)

7.9. International Research Journal of Medicine and Medical Sciences (Open Acess)

7.10. Journal of Isakos (Open Acess)

8. LIVROS E CAPÍTULOS DE LIVRO

8.1. Livro: Classificações em Ortopedia. 3ª edição. 2019

8.2. Capítulo de livro: Transplante de Condrócitos, livro: Da Simulação à prática – Cirurgia do Joelho. 2019

8.3. Capítulo de livro: Reconstrução anatômica do ligamento cruzado anterior. Livro: Joelho Agudo. 1ª edição. 2020

8.4. Capítulo de livro: Reconstrução do ligamento cruzado anterior pela técnica all-inside. Livro: Joelho Agudo. 1ª edição. 2020

8.5. Capítulo de livro: Ligamento cruzado anterior em paciente com esqueleto imaturo. Tratamento cirúrgico da lesão do LCA. Livro: Joelho Agudo. 1ª edição. 2020

8.6. Capítulo de livro: Lesão do ligamento cruzado anterior em paciente com esqueleto imaturo. Tratamento cirúrgico – Técnicas. Livro: Joelho Agudo. 1ª edição. 2020

8.7. Capítulo de livro: Lesão do ligamento cruzado anterior em paciente com esqueleto imaturo. Reconstrução transepifisária total do LCA. Livro: Joelho Agudo. 1ª edição. 2020

8.8. Capítulo de livro: Lesão do ligamento cruzado anterior em paciente com esqueleto imaturo. Reconstrução transfisária do LCA Livro: Joelho Agudo. 1ª edição. 2020

9. REFERÊNCIAS

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9.2. Astur DC, Arliani GC, Debieux P, Kaleka CC, Amaro JT, Cohen M. Intraarticular hamstring graft diameter decreases with continuing knee growth after ACL reconstruction with open physes. Knee Surg Sports Traumatol Arthrosc. 2016; 24(3):792-5.

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9.5. Barrett AM, Craft JA, Replogle WH, Hydrick JM, Barret GR. Anterior cruciate ligament graft failure: A comparison of graft type based on age and Tegner activity level. Am J Sports Med. 2011; 39(10):2194-8.

9.6. Chicorelli AM, Micheli LJ, Kelly M, Zurakowski D, MacDougall R. Return to sport after anterior cruciate ligament reconstruction in the skeletally immature athlete. Clin J Sport Med. 2016; 26(4):266-71.

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9.8. Ellman MB, Sherman SL, Forsythe B, LaPrade RF, Cole BJ, Bach BR Jr. Return to play following anterior cruciate ligament reconstruction. J Am Acad Orthop Surg. 2015; 23(5):283-96.

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Danish registry of knee ligament reconstruction. Orthop J Sports Med. 2014; 2(10):2325967114552405.

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either knee after ACL reconstruction: prospective analysis of 2488 primary ACL reconstructions from the MOON Cohort. Am J Sports Med. 2015; 43(7):1583-90.

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10. COMITÊ DE ÉTICA E PESQUISA – PROJETO DE PÓS-DOUTORADO

UNIFESP - HOSPITAL SÃO PAULO - HOSPITAL UNIVERSITÁRIO DA

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: CARACTERIZAÇÃO RADIOLÓGICA DE PACIENTES ESQUELETICAMENTE IMATUROS COM LESÃO DO LIGAMENTO CRUZADO ANTERIOR E MENISCAL

Pesquisador: Eduardo Vasconcelos de Freitas

Área Temática:

Versão: 2

CAAE: 08914119.7.0000.5505

Instituição Proponente: UNIVERSIDADE FEDERAL DE SAO PAULO

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 3.322.460

Apresentação do Projeto:

Projeto CEP/UNIFESP n:0197/2019 (parecer final)

Trata-se de projeto de mestrado de Eduardo Vasconcelos de Freitas. Orientador: Prof. Diego Costa Astu;r Coorientadores: Prof. André Fukunishi Yamada e Prof. Pedro Debieux Vargas Silva; Projeto vinculado ao Departamento de Ortopedia e Traumatologia, Campus São Paulo, Escola Paulista de Medicina, UNIFESP.

-As informações elencadas nos campos "Apresentação do Projeto", "Objetivo da Pesquisa" e "Avaliação dos Riscos e Benefícios" foram retiradas do arquivo Informações Básicas da Pesquisa (PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1276786.pdf, gerado em 1/3/2019)

APRESENTAÇÃO: Avaliar as características clínicas, radiológicas e funcionais associadas à re-ruptura do LCA em pacientes esqueleticamente imaturos submetidos à cirurgia de revisão do LCA e caracterização das lesões meniscais nessa população.

-HIPÓTESE: O slope tibial, slope meniscal e o índice do intercôndilo influenciam nas lesões do ligamento cruzado anterior e meniscais.

Endereço: Rua Francisco de Castro, 55
Bairro: VILA CLEMENTINO **CEP:** 04.020-050
UF: SP **Município:** SAO PAULO
Telefone: (11)5571-1062 **Fax:** (11)5539-7162 **E-mail:** cep@unifesp.edu.br

Objetivo da Pesquisa:

OBJETIVO PRIMÁRIO: Avaliar o tamanho do intercôndilo, slope tibial e slope meniscal a fim de relacionar com as lesões do ligamento cruzado anterior e meniscais.

Avaliação dos Riscos e Benefícios:

Em relação aos riscos e benefícios, o pesquisador declara:

-RISCOS: Possibilidade de quebra de sigilo das informações dos prontuários, o que poderia se configurar como um risco para os participantes e instituições envolvidas, entretanto fica garantido que todas as medidas cabíveis serão tomadas para reduzir ao máximo esse risco, bem como garantimos que somente os pesquisadores envolvidos nesse estudo, aqui citados, terão acesso a essas informações, a fim de diminuir o risco dessa exposição.

-BENEFÍCIOS: Com a identificação dos fatores de riscos associados à lesão do ligamento cruzado anterior e meniscal poderemos utilizar estratégias a fim de prevenir essas lesões, que vem crescendo ultimamente, a fim de tirar o risco negativo que uma lesão do ligamento cruzado anterior e meniscal podem impactar na vida de uma criança em longo prazo, como afastamento do esporte e artrose do joelho de maneira mais precoce.

Comentários e Considerações sobre a Pesquisa:

TIPO DE ESTUDO: estudo retrospectivo de avaliação de exames radiológico de ressonâncias magnéticas de pacientes esqueleticamente imaturos com lesão do ligamento cruzado anterior e meniscal

LOCAL:

PARTICIPANTES: serão acessados 160 prontuários;

-Critério de Inclusão: Pacientes esqueleticamente imaturos com ou sem lesão do ligamento cruzado anterior e meniscal;

-Critério de Exclusão: Pacientes esqueleticamente imaturos com ou sem lesão do ligamento cruzado anterior e meniscal que apresentem a fise de crescimento fechada ou que tenham dados incompletos ou exames de qualidade técnica inadequados.

PROCEDIMENTOS: Estudo retrospectivo para avaliação de exames radiológicos de ressonância magnética do joelho de pacientes esqueleticamente imaturos com ou sem lesão do ligamento cruzado anterior e lesão meniscal, sendo realizada a medida do tamanho do intercôdilo femoral, do slope tibial e do slope meniscal. (mais informações, ver projeto detalhado).

Considerações sobre os Termos de apresentação obrigatória:

1- Foram apresentados os principais documentos: folha de rosto; projeto completo; cópia do cadastro CEP/UNIFESP, orçamento financeiro apresentados adequadamente.

2- Propõe dispensa do TCLE. Justificativa: Estudo retrospectivo com coleta de dados do prontuário apenas.

Recomendações:

Sem recomendações.

Conclusões ou Pendências e Lista de Inadequações:

Respostas ao parecer nº 3.201.567 de 15 de Março de 2019. PROJETO APROVADO.

PENDÊNCIA 1. – A metodologia do projeto está muito resumida. Deve ser informado a origem dos exames radiológicos de ressonância magnética que serão analisados e a origem dos pacientes.

RESPOSTA: Estudo retrospectivo para avaliação de exames radiológicos de ressonância magnética do joelho de pacientes esqueleticamente imaturos com ou sem lesão do ligamento cruzado anterior e/ou lesão meniscal, sendo realizada a medida do tamanho do intercôdilo femoral, do slope tibial e do slope meniscal, com tabulação desses dados seguida de análise estatística dos mesmos através de software de análise estatísticas próprios, feitos por um bioestatísco.

Foram incluídos no trabalho os pacientes esqueleticamente imaturos com ou sem lesão do ligamento cruzado anterior e/ou lesão meniscal e foram excluídos do mesmo os pacientes esqueleticamente imaturos com ou sem lesão do ligamento cruzado anterior e/ou lesão meniscal que tenham dados incompletos nos respectivos prontuários ou exames radiológicos de qualidade técnica inadequados.

Os pacientes que participarão deste estudo são de origem do Ambulatório da Medicina Esportiva do Departamento de Ortopedia e os exames de ressonância magnética utilizados serão os exames realizados por esses pacientes em qualquer momento durante todo seu acompanhamento no Ambulatório da Medicina Esportiva do Departamento de Ortopedia.

PENDÊNCIA ATENDIDA

PENDÊNCIA 2. – Deve ser anexada na Plataforma Brasil, carta de autorização do guardião das imagens e prontuários, permitindo a realização da pesquisa no local. Caso sejam prontuários de pacientes do HSP, lembramos que toda pesquisa a ser realizada no Hospital Universitário – Hospital São Paulo (HU/HSP), ou em qualquer um de seus ambulatórios ou setores, onde sejam

atendidos pacientes, ou trabalhem profissionais da saúde, deverá vir acompanhada de carta de autorização da Coordenadoria de Ensino e Pesquisa do HU/HSP (que pode ser conseguida na Diretoria Clínica do HSP, no 1° andar do Hospital São Paulo).
RESPOSTA: Coletada as devidas assinaturas e anexado na Plataforma Brasil as devidas cartas de autorizações.
PENDÊNCIA ATENDIDA

PENDÊNCIA 3. – Em relação ao pedido de dispensa de TCLE: a dispensa foi solicitada, com a justificativa de se tratar de análise retrospectiva de prontuários. Entretanto, por orientação da CONEP, é considerado que a análise de prontuários não desobriga o pedido de TCLE, o qual deve ser aplicado no sentido de pedir autorização para o seu acesso, já que o prontuário é de propriedade do paciente e não do médico ou do pesquisador (conforme disposto pelo CFM). Uma solicitação de dispensa de TCLE só é aceita, no caso de não ser possível entrar em contato com o paciente (prontuários muitos antigos, impossibilidade de contatar o paciente, paciente já falecido, etc.). Neste caso, na solicitação de dispensa de TCLE deve ser informado que haverá a tentativa de contato, e que a dispensa está sendo pedida somente para os casos em que não for possível encontrar o paciente. Assim, quando da submissão de projeto de pesquisa na Plataforma Brasil, será necessária a inclusão do modelo de TCLE a ser aplicado aos participantes passíveis de serem contatados, solicitando autorização para o acesso ao prontuário. Caso já se saiba de antemão que será impossível o contato com todos os pacientes, favor deixar claro, no campo de solicitação de dispensa, os motivos desta impossibilidade e neste caso, não será necessário enviar o modelo de TCLE para análise. (Resolução CFM n° 1997de 2012; Constituição federal/88, art. 5°, XIV; e Resolução CFM n° 1605 de 2000, Art. 1°).
RESPOSTA: Confeccionado o Termo de Consentimento Livre e Esclarecido, seguindo as recomendações da CONEP, e anexado como documento na Plataforma Brasil. Segue o modelo no final deste arquivo.
PENDÊNCIA ATENDIDA

PENDÊNCIA 4. – Deve ser enviada declaração, assinada pelo pesquisador, de garantia de sigilo e anonimização dos dados e de responsabilização por qualquer problema em relação a quebra de sigilo dos participantes.
RESPOSTA: Feita a declaração de garantia de sigilo e anonimização dos dados e de responsabilização por qualquer problema em relação a quebra de sigilo dos participantes e

enviada como documento em anexo na Plataforma Brasil.
PENDÊNCIA ATENDIDA

PENDÊNCIA 5. – Adequar, no formulário de informações básicas da Plataforma Brasil, o campo "Riscos": Conforme orientação da CONEP, lembramos que qualquer pesquisa com seres humanos pode causar algum risco, por mínimo que seja. No que diz respeito a esta pesquisa, por exemplo, a possibilidade de quebra de sigilo das informações dos prontuários poderia se configurar como um risco para os participantes e instituições envolvidas.
RESPOSTA: Possibilidade de quebra de sigilo das informações dos prontuários, o que poderia se configurar como um risco para os participantes e instituições envolvidas, entretanto fica garantido que todas as medidas cabíveis serão tomadas para reduzir ao máximo esse risco, bem como garantimos que somente os pesquisadores envolvidos nesse estudo, aqui citados, terão acesso a essas informações, a fim de diminuir o risco dessa exposição.
PENDÊNCIA ATENDIDA

PENDÊNCIA 6. – O cronograma informado no formulário de informações básicas da Plataforma Brasil indica que parte do estudo já estará sendo iniciada antes da aprovação do protocolo. Favor esclarecer e será necessário adequar. Lembramos que nenhum estudo pode ser iniciado antes da aprovação pelo CEP/UNIFESP. Conforme o disposto pela Norma Operacional n° 001 de 2013, item 3.3.f, todos os protocolos de pesquisa devem conter um cronograma que descreva a duração total e as diferentes etapas da pesquisa, com compromisso explícito do pesquisador de que a pesquisa somente será iniciada a partir da aprovação pelo Sistema CEP-CONEP". O cronograma deve ser anexado na Plataforma Brasil, de forma individualizada, em campo próprio para isso (Cronograma).
RESPOSTA: Informo que houve atraso no envio do projeto ao CEP por minha parte, portanto já foi realizada a atualização do cronograma.
PENDÊNCIA ATENDIDA

Considerações Finais a critério do CEP:
O CEP informa que a partir desta data de aprovação, é necessário o envio de relatórios parciais (semestralmente), e o relatório final, quando do término do estudo.

Este parecer foi elaborado baseado nos documentos abaixo relacionados:

Tipo Documento	Arquivo	Postagem	Autor	Situação
Informações Básicas do Projeto	PB_INFORMAÇÕES_BÁSICAS_DO_PROJETO_1276786.pdf	11/04/2019 10:16:18		Aceito
Outros	PENDENCIAS.docx	11/04/2019 10:15:57	Eduardo Vasconcelos de Freitas	Aceito
Declaração de Instituição e Infraestrutura	CARTA_COEP.pdf	10/04/2019 00:24:38	Eduardo Vasconcelos de Freitas	Aceito
Declaração de Instituição e Infraestrutura	AUTORIZACAO_COEP.pdf	10/04/2019 00:24:22	Eduardo Vasconcelos de Freitas	Aceito
Declaração de Pesquisadores	DECLARACAO_CONFIDENCIALIDADE.pdf	10/04/2019 00:23:20	Eduardo Vasconcelos de Freitas	Aceito
TCLE / Termos de Assentimento / Justificativa de Ausência	TCLE.docx	10/04/2019 00:22:37	Eduardo Vasconcelos de Freitas	Aceito
Projeto Detalhado / Brochura Investigador	PROJETO_MODIFICADO.docx	10/04/2019 00:22:14	Eduardo Vasconcelos de Freitas	Aceito
Folha de Rosto	FOLHA_DE_ROSTO.pdf	18/01/2019 12:46:43	Eduardo Vasconcelos de Freitas	Aceito

Situação do Parecer:
Aprovado

Necessita Apreciação da CONEP:
Não

SAO PAULO, 13 de Maio de 2019

Assinado por:
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11. ARTIGOS PUBLICADOS RELACIONADOS AO TEMA

Original Research

Pediatric Anterior Cruciate Ligament Reruptures Are Related to Lower Functional Scores at the Time of Return to Activity

A Prospective, Midterm Follow-up Study

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Background: Skeletally immature patients show a higher rate of anterior cruciate ligament (ACL) reruptures. A better understanding of the risk factors for an ACL rerupture in this population is critical.

Purpose/Hypothesis: The objective of this study was to analyze preoperative, intraoperative, and postoperative characteristics of pediatric patients undergoing ACL reconstruction and determine the relationship of these factors with an ACL rerupture. It was hypothesized that patients with worse activity scores and knee function at the time of return to activity would have a higher rate of ACL reruptures at midterm follow-up. Additionally, it was hypothesized that most ACL reruptures would occur before age 20 years in the study population.

Study Design: Case-control study; Level of evidence, 3.

Methods: A total of 65 skeletally immature patients (age <16 years) with ACL ruptures underwent reconstruction with a quadruple hamstring tendon graft between 2002 and 2016. Of these patients, 52 were available for the study. Patient characteristics, surgical details, Tegner and Lysholm scores, and ACL reconstruction outcomes were recorded. Patients were analyzed and compared according to ACL rerupture occurrence.

Results: Of the 52 patients, 18 (34.6%) experienced an ACL rerupture after reconstruction. The majority of reruptures (77.8%) occurred before age 20 years. There were 2 patients who sustained ACL reruptures during the rehabilitation period before they returned to activity. The majority of reruptures occurred after 12 months (83.2%), with 66.6% occurring after 24 months. Upon returning to activity between 6 and 9 months postoperatively, patients who ended up with intact ACL grafts reported 69% higher mean Tegner scores ($P = .006$) and 64% higher mean Lysholm scores than patients who sustained ACL reruptures ($P < .001$). Within the limits of this study, we could identify no statistical relationship between the rate of ACL reruptures and different sport types, surgical techniques, or associated injuries ($P > .05$).

Conclusion: Skeletally immature patients who underwent ACL reconstruction and sustained ACL reruptures had lower Tegner and Lysholm scores upon returning to activity than patients without ACL reruptures. In addition, most ACL reruptures occurred in patients younger than 20 years (77.8%) and after 24 months postoperatively (66.6%).

Keywords: anterior cruciate ligament; ACL; ACL reconstruction; skeletally immature; return to activity; ACL rerupture; pediatric patients

Several studies have reported up to a 3 times higher rate of graft failure in skeletally immature patients than in adults.[3,7,22,25] The specific reason why an anterior cruciate ligament (ACL) rerupture is more common in this population has not been totally elucidated yet.[28]

Given the scarcity of guidelines and universal protocols for optimal rehabilitation after ACL reconstruction in the pediatric population, validating functional measures in this population, such as Tegner and Lysholm scores, may be essential to calculate the inherent risks of returning to physical activity and minimizing the risk of reruptures.[15,16,23]

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Therefore, the purpose of this study was to analyze preoperative, intraoperative, and postoperative characteristics of pediatric patients who underwent ACL reconstruction and to determine the relationship of these factors to an ACL rerupture. It was hypothesized that patients with low knee function scores after returning to activity would have a higher rate of ACL reruptures. Additionally, it was hypothesized that most ACL reruptures would occur before age 20 years.

METHODS

This was a retrospective, longitudinal cohort study based on prospectively collected data, which was approved by the ethics and research committee of our institution. All patients provided informed consent before their surgery.

A total of 65 skeletally immature patients who underwent ACL transphyseal reconstruction between 2002 and 2016 were considered for this study. The inclusion criteria were patients aged <16 years with ACL injuries and knee radiographs revealing open growth physes who underwent ACL reconstruction with hamstring tendon grafts. The exclusion criteria were previous surgery on the ipsilateral knee, concomitant ipsilateral ligament injuries that required a surgical intervention, tibial spine fractures, and surgery with a non–hamstring tendon graft. Patients who experienced graft failure had their scores, physical characteristics, and surgical technique analyzed and compared with patients who had intact grafts.

The diagnosis of an ACL tear was made clinically (positive Lachman, anterior drawer, and pivot-shift tests)[12] and via magnetic resonance imaging and was confirmed arthroscopically. Anteroposterior and lateral knee radiographs were obtained to evaluate growth stages and long-leg radiographs to determine lower limb alignment and length at the time of the injury.

At the time of presentation after the injury, the characteristics of patients were recorded (age, sex, and Tanner stage, activity). At the time of surgery, surgical characteristics were recorded, including a vertical or anatomic femoral tunnel, type of fixation, graft diameter size, and bone tunnel description. The main purpose of achieving a more vertical femoral tunnel is to decrease the area of injury to the physis. All patients were counseled about the risks of growth disturbances, and a new long-leg radiograph was obtained before returning to activity to evaluate leg-length discrepancies or subtle angular deformities. After surgery (transphyseal isometric or anatomic ACL reconstruction with a quadruple hamstring tendon graft), all patients were referred to physical therapy at the same institution, undergoing the rehabilitation protocol for a period of 6 to 9 months (2-3 times/wk). After this period, patients were released to return to activity according to the following criteria: full knee range of motion, muscular or proprioceptive measurements, and absence of instability or apprehension while performing physical activity.

An author who had no involvement in the clinical care of the patients (E.L.B.C.) administered the Lysholm knee score[19] and Tegner activity scale.[24] The Tegner score graded activity levels from both before the injury (assessed retrospectively, during the patients' first postinjury examination) and 4 weeks after returning to activity. The Lysholm score was administered after the injury and 4 weeks after returning to activity.

All patients were evaluated weekly during the first month, every 15 days in the second and third months, and monthly until the first year after surgery. During all evaluations, a physical examination was performed. Knee radiographs were obtained after 2 weeks and then at 3, 6, and 12 months postoperatively. Magnetic resonance imaging was performed at 6, 12, and 24 months postoperatively or after any possible injury of the operated knee. All data were collected as usual as part of the normal follow-up routine.

In all patients diagnosed with a graft failure, a traumatic episode occurred, and the new injury was diagnosed within 2 to 13 days. The new knee injury episode was considered to define a rerupture.

Statistical Analysis

The independent variables compared in this cohort study were intact ACL graft and ACL rerupture. The Student *t* test was used to analyze the characteristics of the femoral tunnel (vertical vs anatomic) and the femoral and tibial fixation methods. The Mann-Whitney test was used to evaluate age, follow-up, rehabilitation time, graft diameter size, Tanner stage, bone tunnels, and Tegner and Lysholm scores. The chi-square test was used to evaluate the relationship between ACL tear and type of sport activity. A significance level of 5% and 95% CIs were used.

RESULTS

Of 65 patients, 10 did not meet inclusion criteria, and 3 were lost to follow-up, for a total of 52 study patients. Of these patients, 34 had an intact ACL graft and 18 sustained an ACL rerupture (Figure 1).

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Ethical approval for this study was obtained from the Universidade Federal de São Paulo/Hospital São Paulo.

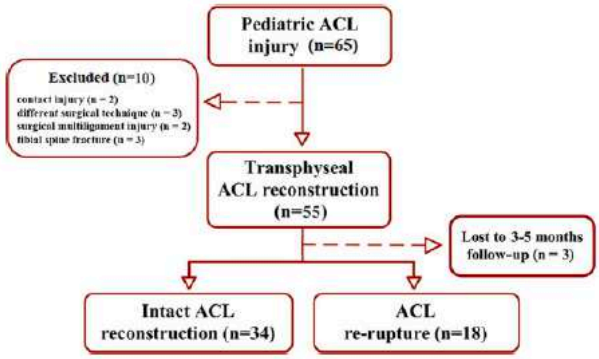

Figure 1. Flowchart of patient inclusion.

TABLE 1
Patient Data[a]

	Intact ACL Graft (n = 34)	ACL Rerupture (n = 18)	*P*
Sex, n (%)			>.05
Male	16 (47)	13 (72)	
Female	18 (53)	5 (28)	
Age, y	13.6 ± 2.5	14.4 ± 1.9	>.05
Follow-up, y	7.4 ± 4.5	4.0 ± 2.8	>.05
Time to return to activity, mo	7.4 ± 1.0	7.5 ± 1.2	>.05
Tanner stage, n (%)			>.05
II	9 (26)	3 (17)	
III	11 (32)	8 (44)	
IV	14 (42)	7 (39)	

[a]Values are presented as mean ± SD unless otherwise indicated. ACL, anterior cruciate ligament.

Table 1 shows the characteristics of the included patients. Most ACL reruptures (77.8%) occurred before the age of 20 years (mean, 18.2 ± 2.9 years [range, 14-24 years]). Among the patients who returned to activity, there was no difference in the time to return to activity (intact ACL graft: 7.4 ± 1.0 months [range, 6-9 months]; ACL rerupture: 7.5 ± 1.2 months [range, 6-9 months]). Only 2 patients had ACL reruptures during the rehabilitation period before they returned to activity (2 and 4 months after surgery, both resulting from return to sport before medical approval). Most ACL reruptures occurred after 12 months (83.2%); 66.6% occurred after 24 months (Figure 2).

At 4 weeks after returning to activity, patients with intact ACL grafts reported a mean Tegner score that was higher than patients with ACL reruptures (7.0 ± 0.8 vs 4.9 ± 1.3, respectively; $P = .006$) (Table 2). Only 5.6% of the patients with ACL reruptures regained preinjury levels of activity after 6 to 9 months of rehabilitation. Among patients who did not sustain ACL reruptures, 46.2% increased their activity level after the surgical procedure, 46.2% returned to their preinjury level of activity, and 7.6% returned to a lower level of activity than that before the ACL injury. After returning to activity, patients with

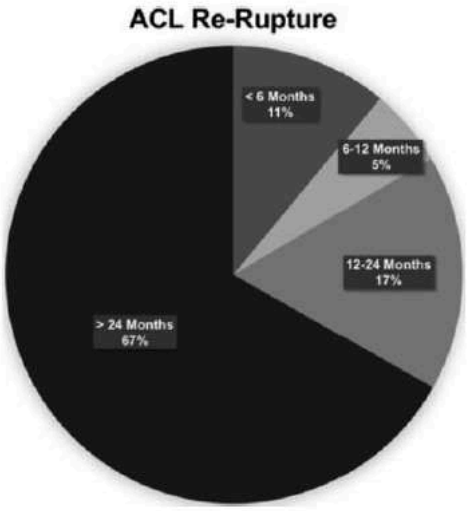

Figure 2. Anterior cruciate ligament (ACL) rerupture rate according to time postoperatively.

TABLE 2
Tegner and Lysholm Scores[a]

	Intact ACL Graft (n = 34)	ACL Rerupture (n = 18)	*P*
Tegner score			
Before injury	7.2 ± 1.0	8.2 ± 1.1	>.05
4 wk after return to activity	7.0 ± 0.8	4.9 ± 1.3	.006
Lysholm score			
After injury	56.3 ± 15.0	57.6 ± 8.5	>.05
4 wk after return to activity	90.6 ± 6.1	58.8 ± 6.7	<.001

[a]Values are presented as mean ± SD. ACL, anterior cruciate ligament.

intact ACL grafts reported a mean Lysholm score that was higher than that for patients who sustained ACL reruptures (90.6 ± 6.1 vs 58.8 ± 6.7, respectively; $P < .001$) (Table 2).

A medial meniscal tear was the most common concomitant injury. There was no significant difference in the incidence of meniscal injuries between patients with and without ACL reruptures (52.9% vs 33.3%, respectively). The most common sport practiced by the patients was soccer (34.6%), followed by basketball and skiing (5.8% each). An ACL injury unrelated to sport activity was common (23%). There was no statistical relationship between the kind of sport and the rate of ACL reruptures ($P > .05$).

Vertical femoral tunnel reconstruction was the most common primary surgical technique compared with anatomic ACL reconstruction in patients with or without ACL reruptures (79.4% vs 88.8%, respectively; $P > .05$). Further details of surgical techniques are shown in Table 3. No growth disturbances or angular deformities were diagnosed during the evaluation.

TABLE 3
ACL Reconstruction Techniques Used[a]

	Intact ACL Graft (n = 34)	ACL Rerupture (n = 18)	*P*
Femoral fixation, n (%)			
Transfix	24 (71)	9 (50)	>.05
Button	8 (23)	6 (33)	>.05
Interference screw	2 (6)	3 (17)	>.05
Tibial fixation, n (%)			
Interference screw	31 (91)	18 (100)	>.05
Button	3 (9)	0 (0)	>.05
Graft size diameter, mm	7.6 ± 0.7	7.3 ± 0.8	>.05
Femoral tunnel size diameter, mm	7.6 ± 0.7	7.7 ± 1.2	>.05
Tibial tunnel size diameter, mm	7.7 ± 0.9	7.8 ± 1.2	>.05

[a]Values are presented as mean ± SD unless otherwise indicated. ACL, anterior cruciate ligament.

DISCUSSION

The main finding of this study was that skeletally immature patients who underwent ACL reconstruction and sustained reruptures had lower Lysholm and Tegner scores when returning to activity than patients who did not sustain ACL reruptures. Low Tegner and Lysholm scores after rehabilitation in patients with reruptures may be caused by a number of factors. One possible factor is the delayed return of quadriceps and hamstring strength, which leads to ineffective muscle control at the expense of a significant muscle deficit that has been shown to last for more than a year.[8,10,14] Exposure of the reconstructed knee to biomechanical conditions in excess of its functional capacity may result in poor clinical outcomes and graft failure.[7,11,21] Besides that, 6 to 9 months of rehabilitation could be insufficient for this population to return safely to sport. Probably, these children have been out of competition for a while and have to re-enter at a significantly higher level while most often not being physically and mentally 100% ready for this with their knee.[13,27]

Another important finding of this study was that ACL reruptures occurred predominantly in patients younger than 20 years (77.8%), in agreement with previous studies that observed that skeletally immature and young adult patients have a 2.5 to 3.5 times increased risk of failure after ACL reconstruction when compared with adult patients.[1,2,7,9,17,25]

Biological and biomechanical characteristics of the graft, such as small diameter, fatigue, and elongation due to functional adaptation, should be evaluated as factors associated with a higher rate of reruptures in the pediatric population.[3,5] Kay et al[18] reported that a predisposition to ACL injuries with high-risk activities (soccer, basketball, football)[10,20] experienced by these patients may be more predictive of reruptures than the intrinsic reconstructed ligament strength, demonstrating that adherence to activity restriction during rehabilitation is critical. In our study, we did not identify a significant relationship between the technique used, graft characteristics, or rehabilitation time and whether an ACL rerupture occurred.

In this study, ACL reruptures occurred predominantly after 24 months of follow-up and may be related to the period of corporal and behavioral transition of patients in this age group.[18] During the same time period postoperatively, the graft is more integrated to the bone, but it may not yet have matured enough to withstand the stress demanded by a more developed musculoskeletal structure and a higher level of sport competition.[3,4] In another study with patients aged 16 to 18 years, Dekker et al[7] found similar results to the present study, with an average time of 26.5 months between primary ACL reconstruction and an ACL rerupture.

An ACL tear is frequently the first major injury in patients younger than 16 years. The reported rate of return to sport in the pediatric population is higher than reported rates in the adult population, which vary between 60% and 75%.[6,8,18,22] One of the reasons for the difference in the rates of return to sport when compared with the adult population may be that adults often choose to forgo further sport participation out of fear of reinjuries and prioritization of work activity.

In the present study, during postoperative follow-up, 34.6% of the patients sustained ACL reruptures, and 77% of these injuries occurred during sport practice. Astur et al[3] found a 24.6% rate of ACL reruptures in patients younger than 16 years. When including patients between the ages of 16 and 18 years, the incidence decreased to 21.2%.[3] In the studies of Dekker et al[7] (age <19 years) and Ho et al[14] (age <18 years), the rerupture rate was 32% and 34%, respectively. In a meta-analysis with patients younger than 19 years, Kay et al[18] found an incidence of reruptures of 13%.

The present study is unique in the literature because, to our knowledge, it is the only study that analyzed patients with ACL reruptures who are younger than 16 years and with open physes on radiographs at the time of primary ACL reconstruction. In addition, this study presents a midterm (mean, 7.4 years) follow-up to evaluate the outcomes of skeletally immature patients who underwent ACL reconstruction.

The main limitation of this study is the relatively small sample size, even considering that it is not usual to find a big sample size with ACL reruptures. In addition, it is not possible to ensure that patients with intact ACL grafts at the time of evaluation will avoid an ACL rerupture in the long term.

CONCLUSION

Skeletally immature patients who sustained ACL reruptures at midterm follow-up had lower Tegner and Lysholm scores at 6 to 9 months than patients who did not sustain ACL reruptures. In addition, 77.8% of ACL reruptures occurred in patients younger than 20 years, and 66.6% of ACL reruptures occurred more than 24 months after primary ACL reconstruction.

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The development of the anterior cruciate ligament in the paediatric population

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Abstract

Purpose The aim of this study was to retrospectively compile normative data on the anterior cruciate ligament (ACL) in the paediatric population with magnetic resonance imaging, emphasizing the differences between men and women.

Methods In this retrospective study, musculoskeletal radiologists evaluated length, area, coronal and sagittal inclination of the ACL and inclination of the intercondylar notch. A total of 253 MR examinations (130 males and 123 females between 6 and 18 years of age) were included. The association between measurements, sex and age was considered. Linear and fractional polynomial regression models were used to evaluate the relationships between measurements.

Results ACL length showed significant progressive growth ($p < 0.001$) with age in men and women, without characterization of growth peaks. ACL area in women showed more pronounced growth up to 11 years, stabilized from 11 to 14 years and then sustained a slight reduction. In men, ACL area showed more pronounced growth up to 12 years, stabilized from 12 to 15 years and then sustained slight reduction. Coronal and sagittal inclination of the ACL showed a significant progressive increase ($p < 0.001$) with age in both sexes, progressively verticalizing. The intercondylar roof inclination angle showed significant progressive reduction ($p < 0.001$) with age in both sexes.

Conclusion The area of the ACL does not accompany skeletal maturation, interrupting its growth around 11–12 years. Progressive verticalization of the ACL as well as of the intercondylar notch roof in the evaluated ages was also observed. The clinical relevance of this study is that the ACL presents different angular and morphologic changes during growth in the paediatric population. Since ACL repair is now being performed on younger children, recognition of the normal developmental changes of the ACL is of utmost importance for successful ACL graft placement.

Level of evidence III.

Keywords Anterior cruciate ligament · Knee · Magnetic resonance imaging · Morphometrics

Introduction

The anterior cruciate ligament (ACL) has been extensively studied in the adult population in recent decades [1–3] through arthroscopic or cadaveric analyses or with imaging methods. However, there is a lack of literature addressing its behaviour in different age groups in the paediatric population.

Currently, around 3% of all anterior cruciate ligament injuries occur in skeletally immature patients [4]. Due to the participation of increasingly younger children in competitive sports, these injuries have become more frequent in this age group [5–8]. In these patients, early reconstruction of the ACL has been advocated [5–8]. Despite the potential risk of injury of the physeal plates with consequent growth disorders, ACL reconstruction makes early return to sports activities possible and reduces the incidence of associated chondral or meniscal injuries [9, 10].

Reconstruction of the ACL aims to reestablish the orientation of the native ligament [11]. In surgically managed cases of ACL injury, the position of the graft is an important factor in the surgical outcome [12, 13]. Nevertheless, there are still challenges to overcome in the immature skeleton

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regarding the position of the graft and tunneling of physeal growth. Complications related to the perforation of the physeal plates such as growth disorders and angular deformities are probably underreported in the literature [14–17]. However, there is no consensus in the literature about which graft size is most appropriate for use in children and adolescents or about the physiological dimensions of the ACL in this population. Because an increasing number of younger children are undergoing ACL reconstructions, more comprehensive anatomical data of the paediatric knee are necessary.

Therefore, the objective of this study is to retrospectively compile data on the anterior cruciate ligament (ACL) in the paediatric population, emphasizing the differences between sexes, in order to better understand the particularities of the ACL in each age group and thus contribute to successful ACL reconstruction.

Materials and methods

Patient selection and MR imaging examinations

Data from consecutive MRIs of the knee performed between 2015 and 2016 of patients aged 6–18 years ($n=298$) were collected by the Picture Archiving and Communication System (PACS)(version 11.4.1.1102) (Table 1). Exams with T1- and T2-weighted sequences in the sagittal, coronal and axial planes adequately showing the evaluated structures were included.

Patients with partial or total anterior cruciate ligament injuries, prior surgical manipulation of the knee, fractures or deformities of the distal femoral or proximal tibia, malformations or orthopaedic syndromes were excluded. The ligament was considered previously torn when any of the following MRI signs was identified: discontinuity, abnormal contour or abnormal signal intensity of the ACL [18]. Patients were also excluded if their imaging report included a diagnosis or clinical history of previous ACL injury or knee sprain. A total of 253 MR examinations, 130 males and 123 females between 6 and 18 years of age, were included. Both knees were imaged in 41 patients (18 males and 23 females).

Table 1 Knee examinations performed in 1-year-Interval patient age groups

Age (years)	Number of knee MR examinations ($n=253$)	n (male)	n (female)
6	14	9	5
7	21	12	9
8	19	9	10
9	20	10	10
10	20	10	10
11	20	10	10
12	20	10	10
13	20	10	10
14	19	9	10
15	20	10	10
16	20	10	10
17	20	10	10
18	20	10	10

In all patients, imaging was performed using a 1.5-T MRI scanner (Magnetom Symphony, Siemens; Magnetom Avanto, Siemens; Brivo MR355, GE; Signa HDx, GE; Optima MR360, GE). The knees were positioned at full extension and were imaged using an eight-channel knee coil. Coronal and sagittal T1-weighted FSE images were acquired with the following parameters: 400–650/9–10 (repetition time msec [TR]/ echo time [TE] msec), 14–15 cm field of view. The parameters for sagittal, coronal and axial T2-weighted FSE images with fat suppression were: 2500–4000/42–60 (TR/TE), field of view of 14–15 cm. For all sequences, the section thickness was 3.5 mm with an intersection gap of 0.5–1.5 mm and a matrix of (256–512) x (192–256).

All measurements were performed twice by the first evaluator (musculoskeletal radiologist with 4 years of experience), with a 3-month interval between measurements. A second evaluator (musculoskeletal radiologist with 7 years of experience) independently performed a second reading of all measurements. Each investigator was blinded to the other investigator's findings.

The following data were grouped according to a 1-year age interval and patient sex. For each examination, the values were measured with the OsiriX DICOM viewer (version 6.0.2).

MR measurements

ACL length

On a midline sagittal image best depicting the ligament, the most posterosuperior point of the ACL femoral insertion was adopted as a proximal reference, and the most anterior point of its tibial insertion as the distal limit. (Fig. 1a).

ACL area

The longitudinal length of the ACL was divided into two identical halves, with the anteroposterior and laterolateral diameter measured at the midpoint, that is, at the transition from the proximal half to the distal half. At this point, the anteroposterior diameter (Fig. 1b) was measured using the sagittal plane, while the laterolateral diameter (Fig. 1c) was measured using the axial plane. The area at this point

was calculated with the formula for oval / circular structures (0.5 x mediolateral width x 0.5 x anteroposterior width x Pi), as performed by Anderson et al. [19].

Intercondylar roof inclination angle: this angle was created between a line drawn along the edge of the intercondylar roof (Blumensaat's line) and the long axis of the femur on a midline sagittal image [2]. (Fig. 1d).

ACL sagittal inclination angle

This angle was created between a line paralleling the midlateral tibial plateau and a line demarcating the anterior-most margin of the ACL, drawn on the midline sagittal image best depicting the ACL [20] (Fig. 2b).

ACL coronal inclination angle

This angle was created between a line demarcating the medial-most margin of the long axis of the ACL and a line connecting the medial and lateral-most margins of the tibial plateau on the same section, drawn on the midcoronal image best depicting the ACL [20] (Fig. 2c).

The present study was approved by the Ethics and Research Committee of the Federal University of São Paulo (São Paulo, Brazil) (597248/2016).

Statistical analyses

To evaluate the development trajectory of the 5 ACL parameters in a cross-sectional design, the *age-specific reference interval method* (ASRI) was used [21, 22]. ASRI results in terms of R^2 (i.e., shared variance with age) were compared to the R^2 obtained from regular linear regression. Several types of models are implemented in PASS 15, the software used for all the analyses, to model the mean and standard deviation functions, including polynomial, fractional polynomial, and ratios of polynomials [23]. Polynomial, fractional polynomial, and ratios of polynomials models were investigated by considering the goodness-of-fit (R^2), where the best-fit model (with highest R^2 reported) for each parameter was reported separately by sex.

Three radiological measurements were taken from the same subject (two from the first evaluator, and the other from the second evaluator). They were summed and then averaged to create a *parcel*, which is a composite measurement yielding a more precise indicator than that generated from using one single observation per subject [24–26].

To investigate sex differences across the five radiological parameters, *t* tests were used, and effect sizes were reported in Cohen's *d*, where 0.2 is considered a small difference, 0.5 a moderate difference and 0.8 a large difference. The adopted significance level was 0.05.

A sample size of at least 122 children per group (i.e., female and male) produces a two-sided 95.0% confidence interval of a 95.0% reference limit, with a width only 22.0% of the width of a 95.0% reference interval. This calculation assumed that the age distribution is uniform and that the reference limit may be computed at any age value. Therefore, the total number of children under the parameters described above should be at least 244 [27].

Intraclass coefficient correlations (ICC) were used to evaluate the intra- and inter-observer reliability. Coefficient of variation (CV) was calculated as a measure of relative dispersion of the variable. Standard error of mean (SEM) indicates the uncertainty around the estimate of the mean measurement.

Results

Supplementary Table 1 shows the clinical indications for performing MRI examinations of the studied sample. Supplementary Fig. 1 presents a box plot graph of the patients' height according to sex in the different age groups. Table 2 shows the best-fitted models considering linear and non-linear models, the R^2, the estimated model and the maximum value obtained from the estimated model. Table 3 shows descriptive statistics of the average means for the three assessments across the five parameters (parcels), intraclass coefficient correlations for intra- and inter-observer variability (ICC), coefficient of variation (CV) and standard error of mean (SEM).

The largest differences in terms of sex (i.e., evaluated via Cohen's *d*) were obtained for the following measurements, in descending order: intercondylar roof inclination angle (Cohen's $d = 0.70$), ACL coronal inclination angle (Cohen's $d = 0.64$) and ACL sagittal inclination angle (Cohen's $d = 0.60$). Regarding the R^2, age is strongly related for ACL length (for females, non-linear $R^2 = 0.64$). The three parameters with the highest variance explained by age for both sexes were: ACL length, ACL coronal inclination angle and ACL sagittal inclination angle. Supplementary Tables 2–6 show the percentile values across the different ages.

ACL length showed significant progressive growth ($p < 0.001$) with age, without growth peaks (Fig. 3). In women, the highest value was found at 15 years ($p50 = 33.4$ mm). In men, the highest value was found at 16.1 years ($p50 = 37.1$ mm).

ACL area in women showed more pronounced growth up to 11 years, with relative stabilization of values between 12 and 14 years and a slight reduction between 15 and 18 years (Fig. 4). The highest value was found at 12.7 years ($p50 = 18.6$ mm^2). In men, ACL area presented more pronounced growth up to 12 years, with relative stabilization of values between 12 and 15 years and a slight reduction

Table 2 Best-fitted models, R^2, the estimated model, and the maximum value obtained from the estimated model

Female						Male				
Parameter	Linear coefficient (p value)	Model linear adjusted R^2	Best non-linear model	Non-linear R^2	Non-linear model's maximum growth point (years)	Linear coefficient (p value)	Model linear adjusted R^2	Best non-linear model	Non-linear R^2	Non-linear model's maximum point (years)
ACL length	0.70 (<0.001)	0.47	$x+x^2$	0,64	15.04	1.07 (<0.001)	0.59	$x^3 + x^3\mathrm{LN}(x)$	0.66	16.09
ACL SIA	0.69 (<0.001)	0.20	$\sqrt{x}+\mathrm{LN}(x)\sqrt{x}$	0.26	16.35	1.00 (<0.001)	0.37	$x^2 + x^3$	0.43	15.90
ACL CIA	1.55 (<0.001)	0.44	$1/x^2+x^3$	0.49	NA	1.71 (<0.001)	0.53	$x^3 + x^3LN(x)$	0.53	18.51
Intercondylar roof inclination angle	−0.12 (n.s.)	0.01	$1/\sqrt{x}+LN(x)/\sqrt{x}$	0.01	8.65	− 0.36 (<0.001)	0.09	$x^3 + x^3LN(x)$	0.11	5.55
ACL area	0.35 (0.002)	0.06	$x+\sqrt{x}$	0.31	12.75	0.60 (<0.001)	0.12	$\sqrt{x}+x^2$	0.31	13.23
Legend: NA = no computable maximum										

ACL anterior cruciate ligament; *SIA* sagittal inclination angle; *CIA* coronal inclination angle

Table 3 Descriptive statistics

Parameter	Whole sample			Female			Male			p value	Cohen's d	ICC		SEM	CV
	N	Mean	SD	N	Mean	SD	N	Mean	SD			Intra-observer	Inter-observer		
ACL length	253	31.7	4.5	124	30.9	3.6	129	32.4	5.2	<0.001	0.34	0.86	0.92	0.28	0.14
ACL sagittal inclination angle	251	51.9	6.0	124	53.8	5.4	127	50.1	6.1	<0.001	0.64	0.89	0.80	0.38	0.11
ACL coronal inclination angle	252	55.9	9.0	124	58.8	8.3	128	53.2	8.8	<0.001	0.65	0.96	0.57	0.57	0.16
Intercondylar roof inclination angle	253	42.3	4.2	124	40.9	3.7	129	43.7	4.2	<0.001	0.70	0.87	0.69	0.26	0.10
ACL area	247	17.3	5.7	121	16.2	4.6	126	18.4	6.3	0.00	0.40	0.28	0.65	0.36	0.32

To investigate sex differences across the parameters, t tests were used, and effect sizes were reported in Cohen's d standardized

SD standard deviation, *ICC* intraclass coefficient correlations, *SEM* standard error of mean: indicate the uncertainty around the estimate of the mean measurement, *CV* coefficient of variation: calculated as a measure of relative dispersion of the variable

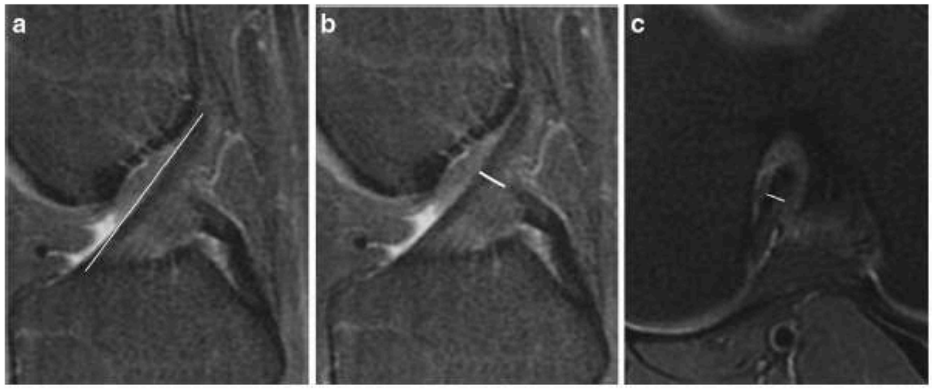

Fig. 1 ACL length, ACL anteroposterior width and ACL laterolateral width. **a** FSE sagittal MR image. ACL length was measured from the posterosuperior to the most anteroinferior point of the ACL. **b** ACL anteroposterior width was measured on sagittal MR images at the middle point of the ACL. **c** FSE axial MR image. ACL laterolateral width was measured at the middle point of the ACL

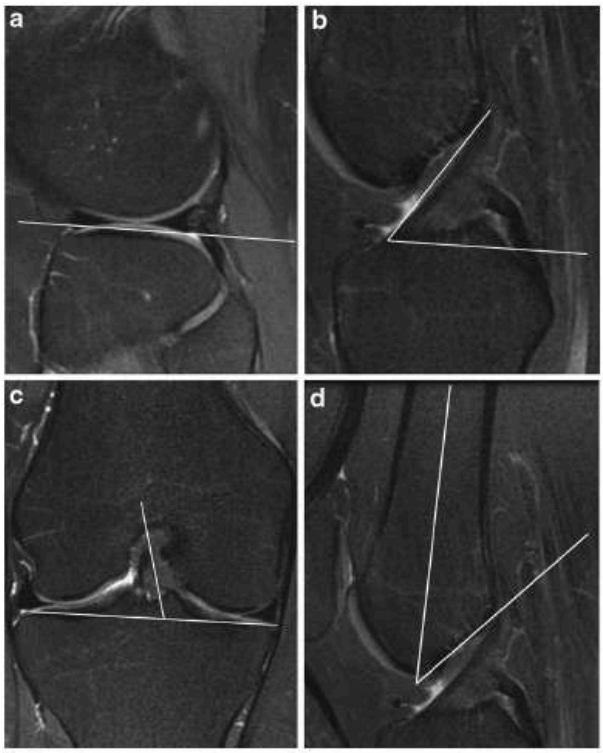

Fig. 2 ACL sagittal and coronal inclination angle and intercondylar roof inclination angle. **a** FSE sagittal MR image. The plane of the tibial plateau is demarcated on a lateral image. **b** On the sagittal midline MR image, the plane of the tibial plateau is superimposed, forming an angle with the anterior-most margin of the ACL (ACL sagittal inclination angle). **c** FSE coronal MR image. The medial border of the ACL and the plane of the tibial plateau were used to determine the ACL coronal inclination angle. d FSE sagittal MR image. The intercondylar roof inclination angle was measured between a line along the intercondylar roof and the longitudinal femoral axis

between 15 and 18 years. The highest value was found at 13.2 years ($p50 = 21.8$ mm^2).

The intercondylar roof inclination angle showed significant progressive reduction ($p < 0.001$) with age, with progressive verticalization of the intercondylar notch roof in the ages evaluated. The ACL coronal inclination angle showed a significant progressive increase ($p < 0.001$) with age, progressively verticalizing in the evaluated age groups (see Fig. 6). In women, a more marked increase was seen from 6 to 9 years. A progressive increase was observed in men, however, it was more linear and homogeneous than in women. The ACL sagittal inclination angle also showed a significant progressive increase ($p < 0.001$) with age, progressively verticalizing in the evaluated age groups (Fig. 5). In women, a more marked increase was observed up to 10 years, with the highest value found at 16.3 years ($p50 = 56.1°$). In men, a progressive, linear and homogeneous increase was observed, with the highest value at 15.9 years ($p50 = 54.2°$).

Discussion

The most important finding of the present study was that the ACL presents different angular and morphologic changes during growth between men and women in the paediatric population. Its length shows significant progressive growth ($p < 0.001$) with age, without achieving growth peaks. The ACL area in women shows more pronounced growth up to 11 years, stabilizes from 11 to 14 years and then undergoes a slight reduction. In men, the area shows more pronounced growth up to 12 years, stabilizes from 12 to 15 years and then suffers a slight reduction. Significant progressive verticalization of the ACL was also seen, as well as significant progressive verticalization of the intercondylar notch roof in the evaluated ages.

When the height growth curve in the population was analysed, it was observed that the age of greatest height growth rate (growth spurt) in girls occurs between 11 and 13 years and in boys between 13 and 15 years [28, 29]. Thus, the growth of ACL length does not follow the height growth curve.

Anderson et al. [19] analysed ACL area at the outlet of the intercondylar notch in 100 high school basketball players,

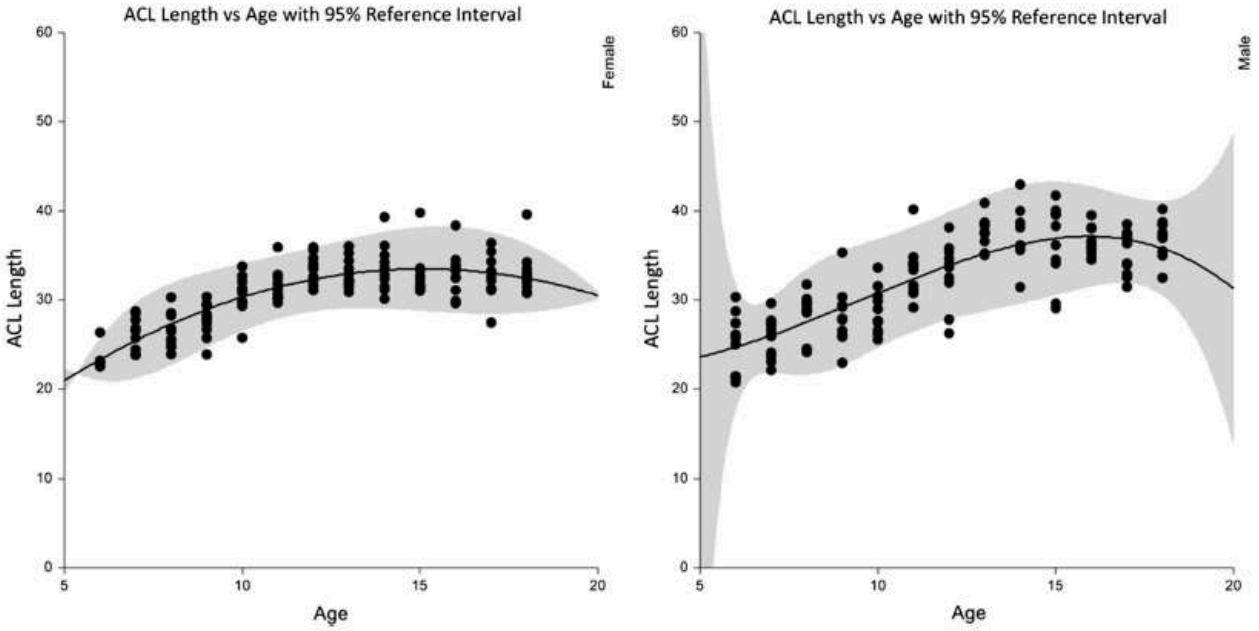

Fig. 3 ACL length as a function of patient age and sex. Polynomial regression curves, with corresponding 95% confidence intervals (shaded) for the model $(1 + (3.702) * age - (0.123) * age^2)$ for female and for the model $\left(1 + (0.0361) * age^3 - (0.0116) * \ln age * age^3\right)$ for male

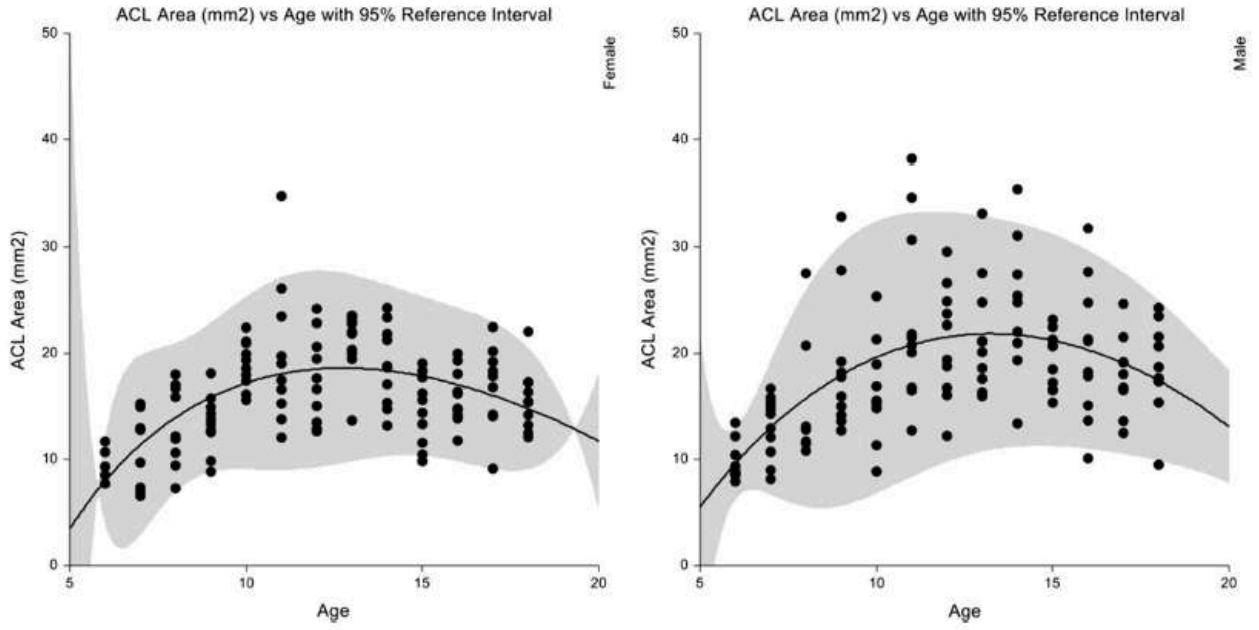

Fig. 4 ACL area as a function of patient age and sex. Polynomial regression curves, with corresponding 95% confidence intervals (shaded) for the model $1 - (8.463)age + (60.445)\sqrt{age}$ for female and $1 + (26.271)\sqrt{age} - (0.136)^2$ for male

observing a mean area of 36.1 mm^2 in women and 48.9 mm^2 in men, values higher than those found in our study. Such differences can be attributed to the use of different measurement techniques and to a focus on different populations and age groups. In a study with children under 13 years of age, Tuca et al. [30] observed that ACL volume plateaus at 10 years, in agreement with results obtained in our study.

The ACL area does not accompany the growth of its length or the height development of skeletally immature individuals. On the contrary, a relative reduction of the area

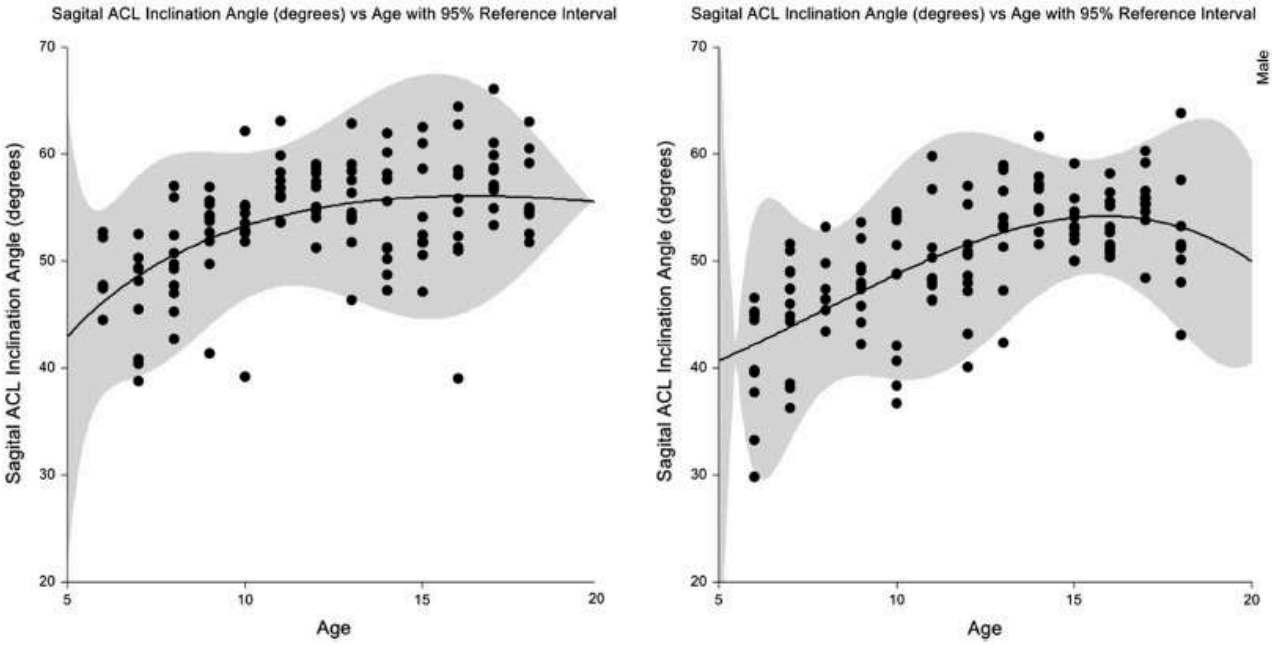

Fig. 5 ACL sagittal inclination angle as a function of patient age and sex. Polynomial regression curves, with corresponding 95% confidence intervals (shaded) for the model $\left(1 + 65.082\sqrt{age} + \log(age)\sqrt{age} * (-13.574)\right)$ for female and for the model $(1 + (0.210) * age^2 - (0.008) * age^3)$ for male

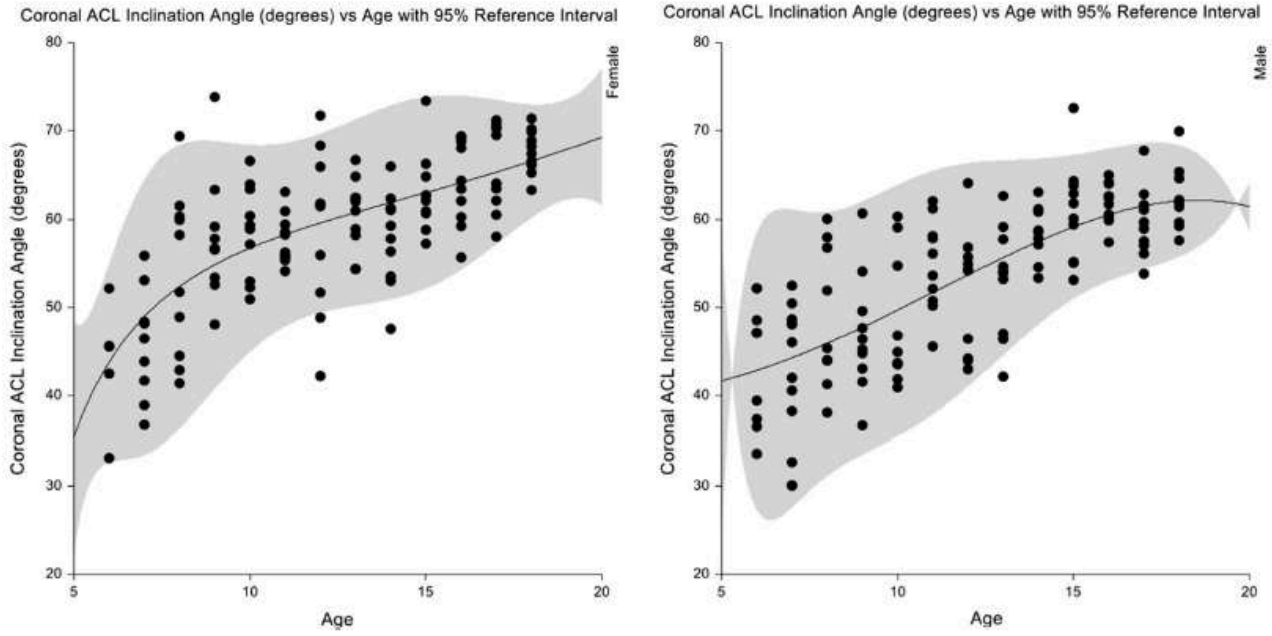

Fig. 6 ACL coronal inclination angle as a function of patient age and sex. Polynomial regression curves, with corresponding 95% confidence intervals (shaded) for the model $(1 - (679.354) * \frac{1}{age*age} + (0.001) * age^3)$ for female and for the model $\left(1 + (0.035) * age^3 - (0.011) * \ln(age) * age^3\right)$ for male

between 15 and 18 years was observed, perhaps due to the predominance of growth in length. In contrast to the height growth curve, in which linear growth is usually observed up to puberty, with peak growth at subsequent ages [28, 29, 31], ACL area interrupts its growth around 11–12 years, just at the moment when the pubertal spurt begins [28, 29,

31]. This discrepancy between height growth and ACL area growth could justify the progressive increase in the incidence of ACL injury in adolescence, due to a disproportion between longitudinal growth, transverse growth and the pubertal growth spurt. In addition, avulsion injuries of the tibial eminence are known to prevail in the 8–14 year age group [32], which until now has been explained in the literature by skeletal immaturity, lapse of periarticular muscle strength or the high elasticity index of the ligament in this age group [32]. However, with the findings of this study, the increased incidence of avulsion injuries in the lower age groups could be interpreted as resulting from more pronounced progressive growth of ACL area at a time when the pubertal growth spurt has not yet begun, that is, by a higher ratio between ACL area and the height and length of the ligament.

Progressive verticalization of the intercondylar notch roof was observed in the ages evaluated, with the intercondylar notch roof slightly more verticalized in women, similar to the findings of Kim et al. [2].

The evaluation of ACL inclination is of fundamental importance, since the adequate positioning and angulation of the reconstructed ligament plays an important role in surgical success. Gentili et al. [20] observed a mean normal sagittal inclination angle of 55.6° in adults, a value close to that found in our study in older age groups. The same author specifies an angle below 45° as a cutoff value to predict ACL injury, a value found in some healthy younger patients in our study. Kim et al. [2] assessed ACL inclination in children and young adults, observing similar results to our study. Therefore, the ACL is progressively verticalized across the different age groups, probably accompanying bone growth and progressive elevation of the intercondylar roof, with the ligament slightly more verticalized in women than in men.

This study had some limitations. Inter- and intra-observer agreement for ACL area was good and low, respectively, although it was acceptable for the other parameters evaluated. These results can be attributed to several factors. First, the ACL is an anatomical structure of small dimensions and margins that are not always well defined, where slight variations in the point of reference for its measurement translated into large variations in the result. In addition, the ACL is a complex anatomical structure, formed by two bands that often overlap or are mildly rotated, making their measurement even more challenging. Finally, due to the MRI slice thickness (3.5 mm) and the intersection gap (0.5–1.5 mm), a partial volume effect was observed in some situations and was detrimental to the precise delineation of ligament margins. Thus, the use of 3D volumetric sequences with isotropic resolution in future studies could provide more accurate measurements of these structures, especially those of smaller dimensions. However, it is worth mentioning that previous studies have already shown good correlation between anatomy and conventional two-dimensional MRI sequences [33, 34]. Additionally, the technique of parceling was used in order to reduce potential calibration bias, permitting normalization of results. Also, longitudinal follow-up of the patients studied was not performed to understand how the evaluated parameters would behave in the same patient over time. Therefore, future studies may provide further clarification through the longitudinal monitoring of ACL growth in a given population.

The most important clinical implication of this study is that the ACL shows different angular and morphologic changes during growth in the paediatric population, with the growth of its area plateauing at 11–12 years. Since ACL repair is now being performed on younger children, recognition of the normal developmental changes of the ACL is important for successful ACL graft placement.

Conclusion

ACL area does not accompany the growth of its length and height growth in children and adolescents. ACL area grows up to the age of 11–12 years, when it undergoes relative stabilization. Progressive verticalization of the ACL in the coronal and sagittal planes was also found, accompanying the verticalization of the intercondylar notch roof.

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Compliance with ethical standards

Conflict of interest The authors declared that they have no conflict of interest.

Ethical approval The present study was approved by the Ethics and Research Committee of the Federal University of São Paulo (São Paulo, Brazil) (597248/2016).

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KNEE

Increased incidence of anterior cruciate ligament revision surgery in paediatric verses adult population

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Abstract

Purpose To evaluate the anterior cruciate ligament graft failure rate in a population of 1376 patients submitted to single-bundle anterior cruciate ligament reconstruction procedure. It was hypothesized that the younger the patient, the greater the chance of a new anterior cruciate ligament graft ligament injury.

Methods A retrospective chart review was performed on patients who had SB anterior cruciate ligament reconstruction between the years, 2001 and 2016, with a minimum post-operative follow-up period of 6 months. The patient population was divided into three groups, according to age: group 1—under 16 years old; group 2—between 16 and 18 years old; and group 3—older than 18 years old. Data collected included sex, laterality and graft choice data.

Results In group 1 (under 16 years old), there were 61 primary ACL surgeries performed and 15 (24.6%) revision ACL surgeries. In group 2 (between 16 and 18 years old), there was 57 primary ACL procedures, of which 10 (17.5%) were revisions. In the group 3 (older than 18 years of age), 1258 surgeries were done with 116 (9.2%) revisions.

Conclusion The rate of ACL revision surgery in patients under 16 years of age was significantly higher than that found in patients older than 18 years old. When compared to the population between 16 and 18 years old, there were a higher number of failure cases, however, statistically non-significant.

Level of evidence IV.

Keywords ACL reconstruction · Graft failure · Knee · Open physis · Paediatric population

Abbreviations

ACL Anterior cruciate ligament
CEP Ethics and Research Committee

Introduction

The incidence of ligament injury in skeletally immature patients increases as participation in sports progresses from recreational to professional in order to achieve high-performance results [9, 18, 25]. Knee injuries are frequent and an anterior cruciate ligament (ACL) tear may affect knee stability and require surgical reconstruction at an earlier age [12, 16, 18, 19].

Patients with advanced stage of pubertal development with ACL injury are commonly submitted to the same ACL reconstruction technique, transphyseal reconstruction through the tibia and femur with graft fixation with

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interference screws or cortical buttons, performed for the adult patient [14, 20, 22]. However, depending on the stage of bone maturation, there are other surgical technique options, from extra articular reconstruction to transepiphyseal reconstruction [8, 10, 17].

Despite a better understanding and acceptable results about ACL reconstruction in skeletally immature patients, with the increase in number of patients submitted to surgery is perceived the number of graft re-tear is also increasing. Factors that lead to graft failure after primary ACL surgery can be related to the size and type of the graft, surgical technique and bony morphology [15]. However, in paediatric population additional factors could decrease the failure rate, considering it seems to be more common than the adult population [23].

The aim of this study was to evaluate the ACL reconstruction revision rate differences between three population age groups: less than 16 years old, between 16 and 18 years old, and greater than 18 years old. The hypothesis of this study was that the younger the patient, the greater the risk of a new ACL tear.

Materials and methods

Between 2001 and 2016, a total of 1376 patients had ACL reconstruction at Instituto Cohen and Federal University of Sao Paulo. All patients underwent arthroscopic surgical reconstruction with either tibial and femoral transphyseal technique or femoral fixation with interference screw or cortical button and tibial fixation with interference screw. Four-strand hamstring tendon grafts were used for patients younger than 18 years old, and four-strand hamstring or patellar tendon grafts were used in patients older than 18 years old. Isometric reconstruction was performed for all patients from the years 2001 to 2011 with a more vertical femoral tunnel. From 2011 to 2016, anatomical reconstruction was performed for patients older than 18 years old and isometric reconstruction continued to be performed for patients under 18 years of age. Excluded from this study were patients who underwent extra articular joint and transepiphyseal ACL reconstruction techniques and patients who chose not to participate or who left the study.

Patients were divided in three different groups by age: group 1 (skeletally immature young patients) under 16 years of age, group 2 (skeletally mature young patients) between 16 and 18 years of age and group 3 (adults) greater than 18 years of age. Radiographic knee images were used to determine open or closed physis. All the ACL reconstructions were performed by the same orthopaedic surgeons, followed the same post-operative rehabilitation protocol that included return to sports between 6 and 9 months after ACL reconstruction procedure. Post-operative range of motion (ROM), quadriceps muscle strength and laxity tests were evaluated weekly for the first post-operative month, then monthly until the sixth to ninth month and finally yearly after the first year.

Graft failure was assessed in all patients after at least 6 months post-operative healing had taken place, and sex, laterality and graft choice data were collected to assess graft failure incidence after primary ACL reconstruction. The present study was performed and approved by Ethics and Research Committee (CEP) from Universidade Federal de São Paulo (São Paulo/Brazil) (1181/11).

Statistical analysis

To assess significant differences among the three groups, data were analysed using the two-proportion equality test. Statistical significance was set at $p < 0.05$ and the selection of a 95% confidence level for all intervals was chosen. As we analysed all surgeries performed in this medical service during the last 16 years, we did not calculate a sample size to correlate different groups.

Results

A total of 1376 patients who underwent ACL reconstruction were included in this study, with 1065 males and 311 females ($p < 0.001$). The laterality of the ACL reconstructed knees was as follows: 715 right and 661 left ($p = 0.04$). In the three age groups: group 1, skeletally immature patients under 16 years of age totalled 61 ACL reconstruction surgeries, group 2 totalled 57 patients skeletally mature patients between the ages of 16 and 18 years, and 1258 adult patients greater than 18 years of age were in group 3.

In the study cohort, 141 patients had ACL revision surgery (10.2%): 15 revisions in group 1, 10 revisions in group 2 and 116 revisions in group 3. There was a significant difference in cases of ACL revision comparing groups 1 and 3 ($p < 0.001$) and groups 2 and 3 ($p = 0.04$) (Table 1).

There was no statistical difference between ACL graft tears or re-tears and operated side (n.s.). There was a significant difference in ACL revision surgery between all patients by sex ($p < 0.001$). However, there was statistical difference comparing groups 2 and 3 ($p = 0.02$) in favour of a higher incidence of re-rupture in males (Table 2).

Discussion

The most important finding of this study was that the number of ACL revisions due to graft failure in patients under 16 years of age was statistically higher than in the older

Table 1 Comparison between the age groups in distribution of "reconstruction primary/revision"

	Primary		Revision	
	N	%	*N*	%
< 16 years old (group 1)	46	75.4	15	24.6
16–18 years old (group 2)	47	82.5	10	17.5
> 18 years old (group 3)	1142	90.8	116	9.2
Total	1376		141	10.2
P values			G1 × G2 = n.s. G1 × G3 = $p < 0.001$ G2 × G3 = $p = 0.04$	

There is no statistical difference between groups 1 and 2 (n.s.), but comparing groups 1 and 3 and groups 2 and 3 there is a statistical difference in the number of ACL revision surgery after graft failure ($p < 0.05$)

Table 2 Comparison between the age groups in distribution of "revisions/gender"

Revision/gender	Male		Female	
	N	%	*N*	%
< 16 years old (group 1)	11	73.3	4	26.7
16–18 years old (group 2)	6	60	4	40
> 18 years old (group 3)	101	87.1	15	12.9
Total	118		23	
P values			G1 × G2 = n.s. G1 × G3 = n.s. G2 × G3 = $p = 0.02$	

According to gender, there was a significant difference in ACL revision surgery between patients ($p < 0.001$). However, there is no difference between primary and revision surgery according to gender when comparing groups 1 and 2 and groups 1 and 3. There is only a difference between groups 2 and 3 in favour of a higher incidence of re-rupture in males

group greater than 18 years of age ($p < 0.05$). However, Barret et al. [6] noted that the ACL revision rate was higher in patients under 25 years of age. We believe there are three different population groups who undergo ACL reconstruction: a paediatric immature skeleton population, a paediatric mature skeleton population and an adult population. The main factors to compare these groups are physeal growth plate characteristics, the ability to understand and perform the correct rehabilitation and avoid re-tear risk and size of graft used [26]. Lumping patients under 25 years of age into one group could be a mistake, since there are differences in physical and behavioural maturity.

Patients under 16 years of age still present bone growth potential most of the time, and therefore, specific features in surgical technique to minimize the risk of injury to the growth plate are warranted. Besides that, small-diameter hamstring tendon grafts, with corporal development, may require in effort below their capacity. Astur et al. [3] in a recent study showed that the graft of immature patient decreased on average 25.3% in diameter during the recent post-operative period. It is also associated with the fact that younger patients adhere in a way less orthodox rehabilitation, often not fearing the consequences of treatment failure [27]. Young patients with mature skeletons commonly already practise sports competitively. Some studies showed that these patients usually return to sports too early, with 96% of them returning to their pre-injury form, much higher than adult patients, with return rate close to 50% [1, 7]. At the same time, this precocity may exemplify increased failure graft ligament rates in ACL reconstruction [14].

The number of revision surgeries was higher in the group of patients under 16 years in age in relation to those patients between the ages of 16 and 18, but without statistical significance (n.s.). The revision ACL rate for under 16 years of age was higher than that of between the ages of 16 and 18. This superiority in the rate of failure of the younger population was also observed, although smaller, by Fauno et al. in which patients less than 13 years of age, between the ages of 13 and 15, between the ages of 15 and 20 and greater than 20 years of age, presented revision rates of 3.2, 6.7, 4.9 and 2%, respectively [11].

Males had a higher ACL re-rupture rate. Although studies have shown that the incidence of primary ACL tear is higher in female patients, behaviour and adherence to physiotherapeutic treatment as well as the degree of energy imposed in men sports may favour the neo-rupture ligament [2, 4, 24]. In addition, male patients practise more frequently sports involving rotational movements, which favour cruciate ligament stress such as soccer and martial arts.

There was no relationship between the affected side (laterality) and re-rupture. There are no data in the literature that justifies the existence of any relationship between laterality and injury [5, 13, 21].

This study had several limitations. All patients were treated in a referral centre for high-level athletes. This may be considered a limiting factor, since the patients may have been subjected to the risk of injury more frequently. This could justify the greater number of reconstruction surgeries of the cruciate ligament than studies already published in the literature and re-rupture rates in adult patients more frequent than others reported in the literature [13]. Moreover, as a retrospective study, some missing information or registration error may have occurred.

The most important clinical relevance of this study is that ACL reconstruction in paediatric patients should be

carefully performed, as the risk of re-rupture seems to be higher. Associated injuries of the knee and early osteoarthritis in such young patients will probably result in even more serious damage to this population.

Conclusion

The rate of ACL revision surgery in patients under 16 years of age (24.6%) was significantly higher than that found in patients older than 18 years old (9.2%).

Compliance with ethical standards

Conflict of interest All authors declare no conflict of interest.

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Ethical approval The present study was performed and approved by Ethics and Research Committee (CEP) from Universidade Federal de São Paulo (São Paulo/Brazil) (1181/11).

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KNEE

Intraarticular hamstring graft diameter decreases with continuing knee growth after ACL reconstruction with open physes

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Abstract
Purpose To evaluate the graft diameter size after one-year follow-up or more of patients Tanner II, III, and IV who were submitted to anterior cruciate ligament reconstruction.
Methods Ten patients [five males (mean age: 14.4 years) and five females (mean age: 13.6 years)] with open physis and anterior cruciate ligament tear were submitted to transphyseal anterior cruciate ligament reconstruction with quadruple hamstrings graft. During the procedure, graft and tunnel size were recorded. After last clinical follow-up (range 1–11 years), an MRI study was requested and their measurements near the tibial tunnel were compared with the graft diameter measured and used during primary procedure.
Results Four patients had Tanner stage II, four patients Tanner stage III, and two Tanner IV. There were statistically significant decreases in the quadruple hamstrings graft diameter size (average of 25.3 %). Mean size at time of surgery was 7.9 mm (±0.87), and mean size measured at different points of follow-up evaluation was 5.9 mm (±0.65).
Conclusion Diameter size of hamstring graft in skeletally immature patients is smaller in most cases. If there is a decrease in the diameter of the graft along postoperative time, the risk of a re-rupture is theoretically further increased. Quadruple hamstring graft decreases a mean 25.3 % in diameter from time of anterior cruciate ligament reconstruction surgery until reassessment period in skeletally immature patients.
Level of evidence IV.

Keywords Anterior cruciate ligament · Tanner stage · ACL reconstruction · Open physis · Children · Graft evaluation

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Introduction

It is known that the younger the patient with an anterior cruciate ligament (ACL) injury, the greater the concern over how to treat it: Should we operate? What kind of surgical technique should be adopted? Should the surgeon drill through the growth plate or not? A horizontal femoral tunnel to achieve a more anatomical reconstruction, or a vertical femoral tunnel to drill a smaller area of the physis? And what type of graft should be chosen for these paediatric patients? [1, 3, 11, 13, 27, 29].

ACL surgical reconstruction in skeletally immature patients is considerably becoming more popular [1, 12, 16, 17, 22, 27, 29, 32]. Complications resulting from physis drilling such as abnormal bone growth or angular deformities are rarely mentioned and probably underreported in

the literature [1, 8, 12, 16, 23, 27, 32]. However, it seems that most patients who did not undergo reconstruction, or wait for skeletal maturity to do surgery, often have associated lesions such as meniscus or chondral injury and consequently will undergo more complex procedures and worse results are expected [2–4, 20].

Transphyseal reconstruction technique where hamstrings graft crosses the growth plate at the tibia and femur was apparently safe for patients classified as Tanner III and IV [6, 10, 18]. Best treatment option for patients Tanner I and II is still controversial [19, 24]. Transepiphyseal techniques have evolved over time and achieved adequate results when treating patients Tanner II causing no damage to the growth plate [7, 9, 14, 25, 26]. However, how this newly graft-reconstructed ligament behaves over time while the young patient grows is still questioned [30].

Few are the studies that report the behaviour of the graft after ACL reconstruction surgery. In a young population, changes on patients' bodily composition are linked to the development of tissues. Based on this information, should the graft grow in size along with other bodily tissues, or reduce since it is now fixed to the tibia and femur of a growing limb? Furthermore, will the surrounding tissue of the graft, which usually necrotizes just after surgery, be replaced by newly formed cells with ligamentous properties and able to adapt to further human development?

The aim of the study was to evaluate the graft diameter size after one-year follow-up or more in patients Tanner II, III, and IV who were submitted to an ACL reconstruction.

Materials and methods

Ten skeletally immature patients were recruited for this study. Demographic data are listed in Table 1. Sex distribution was similar (five males with a mean age of 14.4 years and five females with a mean age of 13.6 years), and mean age was 14 years (range 12.4–15.4 years). The mean follow-up period was 6.7 years, with a range of 1.1–10.1 years. At time of surgery, four patients were Tanner stage II, four patients stage III, and two Tanner IV.

Inclusion criteria were patients younger than 16 years; transphyseal ACL reconstruction, usage of quadruple hamstrings graft, open physis diagnosed through knee radiographs images, and primary surgery. Patients older than 16 years, absence of growth plate in frontal and lateral knee radiographs images, and those who did not allow a follow-up knee MRI study after surgery were not included. All patients meeting the criteria above who underwent an ACL arthroscopic reconstruction with hamstrings graft during the period of 2000–2012 were identified from the senior author's (M.C.) database.

Patients' surgical and epidemiological data were recorded: patient age at time of surgery, type of graft used, tibial and femoral tunnel, graft size measured during surgery, and Tanner stage at time of surgery.

Graft was measured at two different time points: first during surgery, after harvesting graft from the semitendinosus and gracilis, and preparation of the graft for insertion into the patients' knee. Grafts were tightened and half-folded. At this point, a circular millimetre ruler was used to measure the diameter of the graft at its middle point (the one that will be located inside the joint). The tibial and femoral tunnel was set according to the same size of the previously measured graft.

Prospectively, we measured the diameter of the graft through MRI analysis. On MRI, two musculoskeletal radiologists evaluated ligament grafts considering their integrity and size. Ligament graft was measured on coronal T2 fat sat at its intercondylar path near the tibial tunnel. The estimated sectional area of the graft on axial T2 fat sat at its intercondylar path near the tibial tunnel was also estimated.

Patients' height, weight, growth rate and weight gain associated with clinical signs of maturity were used to determine Tanner stage [21, 28].

Approval was obtained from our institutional review board (Universidade Federal de São Paulo) before enrolment of patients into the study.

Table 1 10-patient evaluation: Tanner stage from II to IV, with a follow-up between 1 and 12 years and graft diameter decrease between 12.9 and 33.3 %

Variables	n	Median	SD	Min	Max	*p*	Decreased
Intraoperative graft diameter(mm)	10	7.9	0.87	7	9	<0.001	25.3 %
MRI graft diameter(mm)	10	5.9	0.65	4.7	6.7		
Tibial Tunnel(mm)	10	7.9	0.87	7	9		
Femoral Tunnel(mm)	10	7.9	0.87	7	9		
Chronological age at surgery (years)	10	14		12.4	15.4		
Age during MRI exams (years)	10	20.9		15.2	25.4		
Follow-up (years)	10	6.7		1.1	10.1		

t Student's test

Results

When compared intraoperative graft diameter to MRI postoperative measurements, the quadruple hamstrings graft diameter was significantly smaller at follow-up images. Mean size at time of surgery was 7.9 mm (SD ± 0.87), and mean size measured at different points of follow-up evaluation was 5.9 mm (SD ± 0.65). For all cases there was a decrease in graft diameter. No relationship was found between graft size and time of follow-up and graft size and Tanner stage. The diameter of the graft decreased an average of 25.3 % (range 12.9–33.3 %) ($p < 0.001$) (Table 1; Fig. 1).

Discussion

The major finding of this study was a significant decrease in the graft diameter after at least 1 year of follow-up.

At first time, it is acceptable to agree that the graft would somehow grow along with children's growth. While a child develops her muscles and bones during growth, it would be expected that the ligament hyperthopy as well. Through this process, new cells around the hamstrings graft would be produced and a new vascularization would emerge bringing with it new mechanoreceptors.

Bollen et al. [5] found no changes in graft size when they analysed the characteristics of the graft after ACL reconstruction in five immature patients.

However, the results of the study showed us the opposite since young patients evolved with grafts thinner than those used during the surgical procedure. Some theories are formulated to explain these results: as the patient grows, the newly reconstructed ligament will stretch without hypertrophy, causing a decrease in its diameter. Furthermore, this phenomenon may already start just after surgery as a result of the tension caused to the graft during fixation at the tibia, and this could be intensified due to necrosis of cells around the graft ligament during the healing process. Whereas it is expected that as the patient becomes older, he gains weight and height, living with an even thinner graft than the one used in his surgery would make us think that there is a higher chance of a new lesion. This could be an important reason for higher risk of a new rupture after ACL reconstruction in the paediatric population when compared to the adult population [15, 31]. Therefore, we believe that although narrow, the patient graft is able to adapt and provide sufficient stability for a normal life for most of these patients.

Despite the small number of patients evaluated (loss of follow-up was high due to a great number of patients with follow-up >10 years), it is interesting that in all cases the graft size decreased considerably. These data are enough for us to reflect and better understand the evolution of surgeries performed in skeletally immature patients. The study could be improved if we had an MRI of the contralateral knee to estimate the original ACL diameter at the time of surgery and use it for comparison.

Another limitation is the lack of standardization of follow-up time. However, we wanted to show that the reduction in graft diameter occurs regardless of whether the patient has been operated 1 or 10 years ago. New studies should be conducted to better understand how this operated knee adaptation is possible with a thinner graft ligament, as well as set a default reduction of the graft size according to age and follow-up time.

Diameter size of hamstring graft in skeletally immature patients is smaller in most cases. If there is a decrease in the diameter of the graft along postoperative time, the risk of a re-rupture is theoretically further increased.

Fig. 1 MRI study measurements. Sagittal T2 fat sat over his intercondylar path near the tibial tunnel was carried out. **a** Axial and coronal MRI views in the same correspondent sagittal view to define area and diameter from the graft used

Conclusion

Quadruple hamstring graft decreases a mean 25.3 % (range from 12.9 to 33.3 %) in diameter from time of ACL reconstruction surgery until reassessment period after surgery in skeletally immature patients.

Compliance with ethical standards

Conflict of interest All authors declare no conflict of interest.

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CASE REPORT

Twin athlete brothers with open physes operated for ACL reconstruction on the same day, but with different elapsed times after injury: a 5-year follow-up

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SUMMARY

We present the case of twin brothers with open physes who practiced judo to a high level and were operated on the same day for anterior cruciate ligament reconstruction. One of them was injured a year before surgery, and the other was injured a month before the procedure. The brother who chose to undergo a conservative treatment sustained meniscus injury afterwards and showed lower objective results when evaluated 5 years after surgery.

BACKGROUND

The number of injury records for anterior cruciate ligament (ACL) of the knee in patients with immature skeleton has increased considerably in recent years. This expansion is believed to be directly related to the practice of sports in professional levels, which is increasingly common in young patients. Currently, young patients with immature or nearly mature skeleton are believed to be ready to undergo arthroscopic transphyseal ligament reconstruction. These patients match Tanner's classification for stages III and IV. However, for all patients with Tanner stages I and II, the debate continues and results in different approaches in the presence of the injury.[1 2] Since these patients have a high physical development potential, transphyseal reconstruction might wound the growing physes and consequently result in sequelas during this further development. For this reason, and given how difficult it was to classify the patient according to Tanner stages,[3] many surgeons decide to wait a specific amount of time to allow for further development of the injured patient, taking them away from sports activities until surgery is recommended. In practical terms, though, it proves to be a difficult challenge convincing the patient and their family of how important it is to restrict daily activities, and new injuries deriving from their engagement in such activities with an injured knee start to appear. In this report, we present a case of twin brothers who practiced the same sporting activity, judo, in professional level. Both of them suffered torn ACL and were operated on the same day and by the same surgeon, with the same technique and graft. However, one of them had been injured a month before, while the other had sustained injury 12 months before. Follow-up was performed through physical and imaging examinations. We will show how each patient evolved differently after 5 years, based on these examinations and on validated questionnaires.

CASE PRESENTATION

Patients 1 and 2 are 22-year-old identical twins; they have practiced judo since the age of 10 and have been professional judo competitors in youth categories in their home country.

At the age of 16, patient 2 sprained his right knee and was diagnosed with a torn ACL. The patient was still in his development phase, as open physes were diagnosed through X-rays. An orthopaedist and a paediatrician evaluated his case and classified him in Tanner stage III. Although the medical team recommended surgery for ACL reconstruction, the patient decided not to undergo surgery at that moment, due to the imminent selection of the national judo team who would participate in the Pan American games. The patient and his family were advised on the possible consequences of their decision; physiotherapeutic treatment was suggested until the patient reached skeleton maturity. Nevertheless, recurrent episodes of knee instability followed, along with progressive pain, making him increasingly incapable of performing his sporting activities.

Eleven months after patient 2's injury, patient 1 also sprained his right knee during judo practice and was diagnosed with a torn ACL. Given the evident dissatisfaction showed by his brother, patient 1 agreed to undergo arthroscopic ACL reconstruction. After 12 months of constant complaints, patient 2 also decided to undergo surgery. Both brothers were evaluated and classified at Tanner stage III. Both surgeries took place on the same day and were performed by the same surgeon. For patient 2, surgery occurred 12 months after his injury; for patient 1, it happened 1 month after.

For both brothers, preoperative examination included the following manoeuvres: Lachman, anterior drawer; pivot-shift; McMurray; Apley; range of motion test; intra-articular leak and muscle trophism (table 1).

INVESTIGATIONS

Patient 2's preoperative MRI showed a torn ACL and longitudinal tear of the posterior horn of the medial meniscus.

Table 1 Physical examination—preoperative and after 5 years

	Anterior drawer	Lachman	Pivot shift	McMurray	Apley	Range of motion	Trophism
Preoperative patient 2	++	++	++	++	+	Slightly reduced	Normal
Preoperative patient 1	++	++	++	+	0	Normal	Normal
Postoperative 5 years patient 2	++	+	+	0	0	Normal	Normal
Postoperative 5 years patient 1	0	0	+	0	0	Normal	Normal

Figure 1 Preoperative MRI of patient 1.

In patient 1's preoperative MRI, a torn ACL was identified with no meniscal changes (figure 1).

TREATMENT

The chosen surgery technique was the same in both cases: arthroscopic transphyseal ACL reconstruction with hamstrings tendon graft and fixation with interference screw on the tibia and on femur. Patient 2 had an associated lesion of the medial meniscus, which was treated with partial meniscectomy.

The patients were submitted to the same physiotherapeutic protocol for 6 months and was treated by the same physiotherapist until complete reintroduction to sports 8 months after surgery.

Both patients are evaluated once every 6 months; they underwent clinical and imaging evaluation, and responded to validated questionnaires 5 years after surgery for parameter comparison and potential differences deriving from immediate or late reconstruction in patients with immature skeleton.

OUTCOME AND FOLLOW-UP

Patient 2 complains about oedemas after heavy exercises and pain when crouching. Patient 1 does not have any complaints.

Physical examination

No statistical difference was found between patients in relation to results taken from questionnaires applied 5 years after surgery. However, in all results, the numbers for patient 1 (the patient operated a month after injury) were higher than the ones for patient 2 (table 2).

In patient 2's postoperative MRI, we see ACL neoligament with preserved thickness and signal and signs of partial resection of the posterior horn of the medial meniscus (figure 2).

In patient 1's postoperative MRI, we see integral ACL neoligament with preserved thickness (figure 3).

In current X-rays, we can see both patients' reconstructed ACL with no axis changes or length discrepancy between lower limbs.

DISCUSSION

There is disagreement on how to approach ACL injuries in younger patients.[1 2 4] When facing a patient with ACL injury and instability, many surgeons choose to conduct a more conservative treatment, while others wait for a higher level of skeleton maturity before they can proceed to reconstructing this structure. Although some evidences show that the maturity staging proposed by Tanner has low intraobserver and interobserver concordance,[3] especially when performed by orthopaedists, a current trend points to the use of this staging as the basis for treatment administration. In this sense, it is currently believed that patients in stages III and IV must undergo surgery, while patients in stages I and II have become the main focus of debates over the more appropriate approach. Nevertheless, most studies that have led surgeons to consider surgical treatment for patients in stages III and IV are only based on the absence of complications,[5] even though evidences suggest a low-complication profile also present in initial stages.[4 6–12] Some studies have tried to identify factors interfering with prognosis and treatment of injuries.[13–15] In the present study, we attempt to identify in a different way the results obtained in a rare case of twin brothers operated on the same day and in the same place, by the same surgeon, but having different elapsed times after injury. With this effort, we were able to compare two patients with immature skeletons and similar characteristics—same age, height and weight and identical genetic features—and

Table 2 Results from questionnaires applied to both brothers 5 years after ACL reconstruction

Questionnaire	Patient 2	Patient 1
VAS	3	0
Tegner	Preoperative: 9/postoperative: 7	Preoperative: 9/postoperative: 8
Lysholm	90	95
SF-36	124.5	126.6

ACL, anterior cruciate ligament.

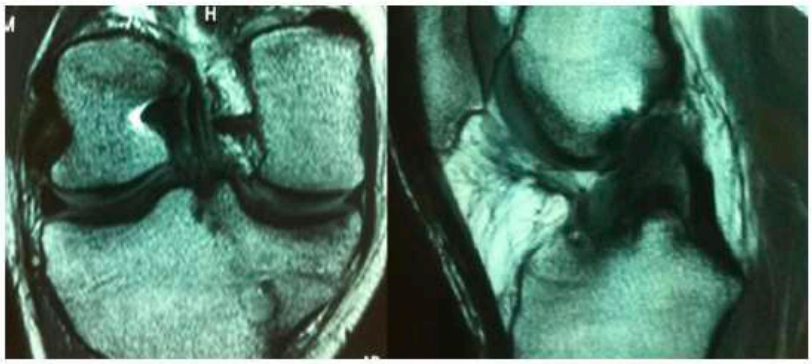

Figure 2 Postoperative MRI of patient 2.

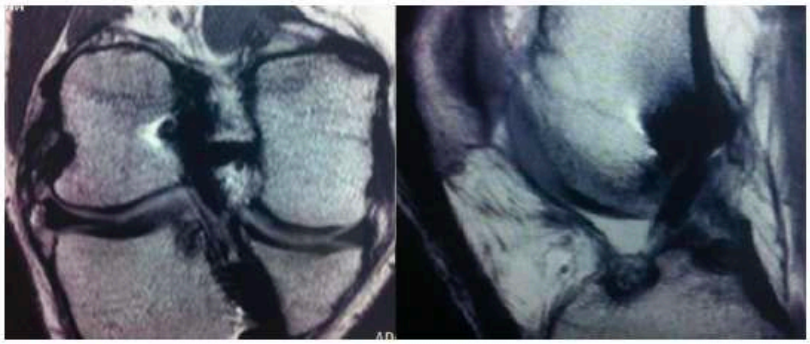

Figure 3 Postoperative MRI of patient 1.

only one differentiating factor. Consequently, it was possible to observe that 5 years after both reconstructions the differences found in questionnaires for joint functioning and quality of life, along with physical examination, derive mainly from the elapsed time between injury and surgery. The patient who waited a year before had his ACL reconstructed developed a higher number of associated injuries (meniscus injury), because of which the surgical procedure was more complex and probably became the biggest factor to make this patient develop lower quality of life and knee function ratings. Although this study focuses on only two cases, the similarities between patients and conditions they were submitted to—which voids many confusing factors—have attracted our attention in relation to the different results achieved from both treatment approaches.

Learning points

- Evaluate Tanner stage.
- Operate as soon as possible.
- Longer waiting time between injury and surgery in active patients leads to new injuries.
- Twins are a good comparison parameter.

Competing interests None.

Patient consent Obtained.

Provenance and peer review Not commissioned; externally peer reviewed.

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CASE REPORT

Unusual case of a surgically treated ACL tear in a 4-year-old patient

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SUMMARY

Anterior cruciate ligament injury in children is an increasingly common disease. We report a rare case of surgical treatment of a 4-year-old patient who presented with an anterior cruciate ligament tear after a high-energy trauma followed by chronic spontaneous subluxation during knee flexion and extension. An extra-articular ligamental reconstruction technique was performed and the child is clinically well 4 years after surgery. Historically, non-surgical treatment has been the main treatment option, however, the indication for surgical reconstruction is increasing as we better understand the histological characteristics of the immature skeleton.

BACKGROUND

Reported incidence of debilitating anterior cruciate ligament (ACL) injury in children has increased mainly because of their frequent participation in competitive sports associated with improved ACL diagnostic techniques.[1–5] A torn ACL in a skeletally immature patient is still a dilemma for orthopaedic surgeons.[1–3 5–7]

Non-operative treatment may include activity modification, bracing and structured rehabilitation, and it is the first treatment option for most orthopaedic surgeons. However, studies have shown poor clinical outcomes for these methods, with an increase in associated meniscal and chondral injuries, as well as a decreased number of patients returning to their previous athletic condition.[1 5 6 8–12]

Surgical treatment with ligament reconstruction restores joint stability, decreasing associated injuries related to a chronic ACL tear.[1 4 5 7 8 10 12] However, surgical reconstruction of the ACL with standard techniques for adult patients is not free of complications for skeletally immature patients. Of major concern is an iatrogenic injury to the growing physis of the femur and tibia when the surgeon drills a tunnel for the ligament graft. This injury could possibly result in asymmetric growing of the limb as well as angular deformity of the knee. In order to avoid this type of complication, an alternative reconstruction technique should be applied, depending on the patient's stage of physeal growth.[1 4 5 10–12]

The Tanner sexual staging system is currently used to define patients' treatment strategy.[2 4] Currently, young patients with immature or nearly mature skeletons (Tanner III and IV) are believed to be ready to undergo arthroscopic transphyseal ligament reconstruction.[13] There is no consensus for patients at Tanner stages I and II.[2 14] A transepiphyseal ACL reconstruction procedure is recommended for Tanner stage II. Some authors, concerned about the technical difficulty of this procedure for Tanner stage I patients, prefer a physeal-sparing procedure.[15] Clinical results of this procedure are good as well.[4 16–19]

We report an unusual case of a 4-year-old patient (Tanner I) with a traumatic tear of the ACL with significant instability and voluntary dislocation of the knee, which underwent an extra-articular ligament reconstruction with iliotibial graft, and a 4-year clinical follow-up.

CASE PRESENTATION

A 4-year-old, 16 kg, 3′5″ tall boy had a traumatic tibial fracture after a wardrobe fell onto his left knee in 2011. He was treated with pain management and casting at a different institution. Thirty days after treatment, he was free of pain, although he frequently reported knee instability during the year following treatment. Also, he could not run or play soccer due to a voluntary provocative knee subluxation, which he was able to perform (video 1).

Owing to an unsatisfactory result, the patient was referred to our service 1 year after the trauma, when a chronic ACL tear (table 1) was diagnosed after clinical evaluation and a MRI study (figure 1). There was no meniscal damage, nor were there chondral lesions or other associated injuries. The patient's bone-age was assessed through radiographic studies. A panoramic X-ray of his lower limbs detected no length discrepancies (figures 2A and 3A). He was classified as Tanner stage I.

Video 1 Spontaneous subluxation of the tibia over the femur.

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Table 1 Clinical evaluation of the knee before surgery, and 6 and 48 months after surgery

Test	Preoperative	6 months postoperative	48 months postoperative
Lachman	+3/3+	+1/3+	+1/3+
Anterior drawer	+3/3+	+1/3+	+1/3+
Pivot shift	+3/3+	Negative	Negative

TREATMENT

The patient underwent surgical reconstruction of the torn ACL using an extra-articular technique[1 6 10 17 20] (video 2 and figure 4). The procedure started primarily with a standard arthroscopic evaluation of the knee joint (figure 5A). Next, a lateral approach was performed at the patients' thigh to dissect and resect the iliotibial band (figure 5B). This structure was detached at its middle and proximal portions (figure 5C) and stitched onto itself to prepare the ligament graft (figure 5D). The graft was passed from the lateral condyle to the medial condyle through the anteromedial arthroscopic portal (figure 5E). At the proximal anteromedial zone of the leg, a 2 cm incision was made to identify the point where the graft would be inserted (figure 5F). After stitching one end of the graft at the posterior zone of the lateral femoral condyle, the loose end of the graft, located at the anteromedial approach, was pulled with tweezers, bypassing the intercondyle notch diving into the joint heading to the proximal zone of the tibia. The loose end of the graft was then fixed distal to the proximal tibial physis through anchor stitches (figure 5G). The final aspect of the new reconstructed ligament is shown in figure 5H. Final aspect of medial skin wounds is shown in figure 5I (video 3). The patient had postoperative brace immobilisation for 6 weeks followed by physical therapy. At week 8, he had full knee extension and 90° flexion.

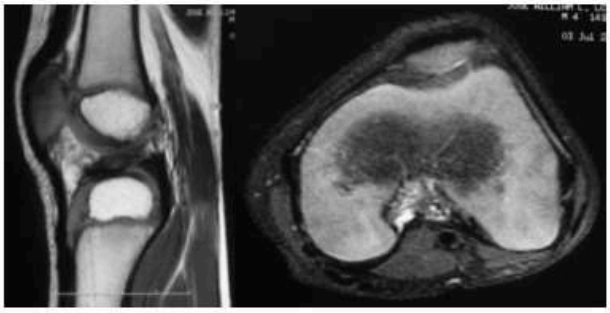


Figure 1 MR of the left knee: preoperative sagittal and axial views. Complete chronic tear of the anterior cruciate ligament (arrow).

Figure 2 Front and lateral radiographs of patient's skeletally immature left knee before (A) and 6 months after (B) surgery.

Figure 3 Lower limb radiographic scan before surgery (A) showing no limb discrepancy. Four years after surgery, there was a 10 mm shortening of the right knee.

OUTCOME AND FOLLOW-UP

Six months after surgery, when his physical rehabilitation was completed, the patient was asymptomatic and able to perform his daily activities, and he was also back to sports. Clinical evaluation showed a knee with almost the same function parameters as the non-injured one (table 1). The patient could no longer voluntarily subluxate his knee as before. Furthermore, radiographic studies showed no bone abnormalities (figure 2B) and MRI showed a newly reconstructed ligament with good positioning (figure 6A, B).

Video 2 Preoperative clinical evaluation: anterior drawer test of the knee, Lachman manoeuvre, pivot-shift test and active quadriceps contraction test.

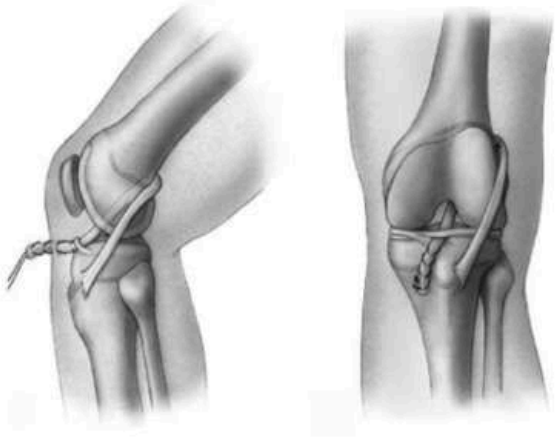


Figure 4 Illustrative surgical technique (Kocher)—physeal sparing, and combined intra-articular and extra-articular reconstruction with usage of an autogenous iliotibial band for prepubescent patients.

Four years after surgery, the patient was still asymptomatic, with normal knee range of motion on both sides, and he was free of pain and had no instability (video 4). Clinical evaluation of the operated knee showed no abnormalities (table 1). Otherwise, a lower limb scan showed a 10 mm lengthening of the left (556 mm—femur 312 mm/tibia 244 mm) compared to the right side (546 mm—femur 303 mm/tibia 243 mm; figure 3B). A MRI was performed and ligament aspect was horizontal and thickened, similar to the earlier MRI performed 6 months after surgery (figure 6C, D).

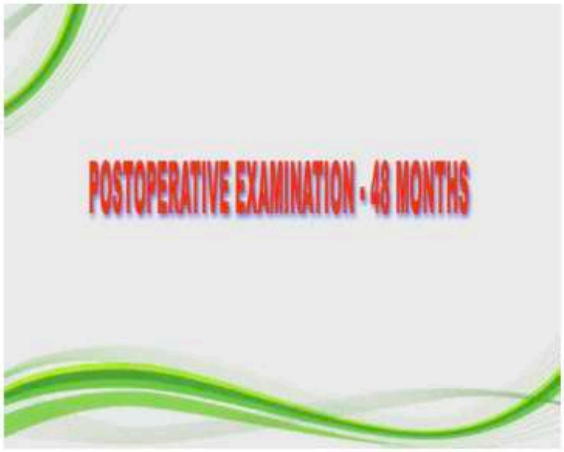
DISCUSSION

This is a unique study describing a 4-year-old patient surgically treated for an ACL injury. Although there is no evidence in the literature for the best treatment, this report justifies its treatment decisions based on reason, and explains why a 4-year-old patient had surgery for an ACL tear. It is known that ACL tears are a frequent injury suffered by athletes. There has been an increase in the incidence of this type of injury, especially in the younger population, since a lot of different sports modalities are now more popular and professionalised.[3 4] However, skeletally immature patients have unique histological and physiological characteristics in their knees, making treatment requirements for their lesions different from those for similarly injured adults.[4 6]

For many years, we believed that non-surgical treatment was the best option for children and adolescents with an ACL tear, focusing on muscle strengthening with rehabilitation and keeping the patient away from sports activities. Surgical ligament reconstruction was considered when patients were older and skeletally mature.[4 5 8 12] Nevertheless, with a better understanding of children's knee physiology, this patient population was categorised according to the Tanners classification. This sexual character development scale is correlated with bone growing velocity, and treatment can be decided based on patients' Tanner stage.[13]

Figure 5 Surgical procedure aspect of an extra-articular anterior cruciate ligament (ACL) reconstruction on the left knee (A-I). (A) Arthroscopic visualisation of the torn ACL. (B) Lateral approach to the thigh with visualisation of the iliotibial band. (C) Isolation of the middle third of the iliotibial band. (D) Proximal detachment of the iliotibial band graft maintaining its distal insertion to Gerdy's tubercle. (E) Preparation of the graft. (F) Anteromedial proximal incision on the leg. (G) Graft is passed over-the-top, intra-articular from lateral to medial. (H) Arthroscopic view of the new-ligament. (I) Clinical evaluation with proved stability of the knee.

Video 3 Surgical procedure. Arthroscopic view of the anterior cruciate ligament injury. Lateral approach to the thigh. Identification of the fascia lata (iliotibial band). Proximal graft detachment. Tubulisation of the graft. Passing the graft medial to lateral. Anteromedial approach to the leg/intra-articular graft passage. Arthroscopic view of the graft. Graft anchor fixation distal to the physeal plate. Lachman test, anterior drawer test and pivot-shift test.



Video 4 Postoperative clinical evaluation 48 months after surgery: anterior drawer test, Lachman manoeuvre, pivot-shift test and active quadriceps contraction test.

A major complication from surgical treatment for an ACL tear in the young population results from physeal perforation and damage when bone tunnels are drilled for graft positioning. However, studies report that patients on Tanner stages III or IV are usually not affected to a great degree on their final growth by this intervention. Based on these results, transphyseal ACL reconstruction may be indicated for these patients.

Patients on early Tanner stages (I or II) still have significant remaining bone growth, and a physeal injury at this point would result in a higher risk of limb growing discrepancies. Currently, the transepiphyseal ligament reconstruction technique is becoming more common for early-staged Tanner patients. Although it is a more time consuming and skilful technique, ligament reconstruction without physeal injury is possible and results are more anatomic than standard extra-articular reconstruction techniques.[6 10 12 16 17 19–21] Nevertheless, on an unusual Tanner I patient with an ACL tear, such as the boy in this report, epiphysis is still underdeveloped and the transepiphyseal technique is highly complex and not always performable.[4 12 18 19]

Although unusual and rarely mentioned in the literature, ACL injuries in children are mostly seen at 8–12 years of age.[22] Our patient was only 4 years old at the time of injury, making it almost impossible to access his epiphysis; also, it is a challenge to keep patients of this age less active in their routine activities. Our patient had a direct trauma to his left knee, which caused an anterior subluxation of the tibia leading to an ACL tear. There is no consensus on how to treat a patient with this type of injury at this age. Although non-surgical treatment is initially preferred for most cases, owing to the difficulty of restricting physical activity in our young patient, waiting for muscle-bone development for future definitive treatment was not a feasible option. Furthermore, knee instability resulting in eventual falls,

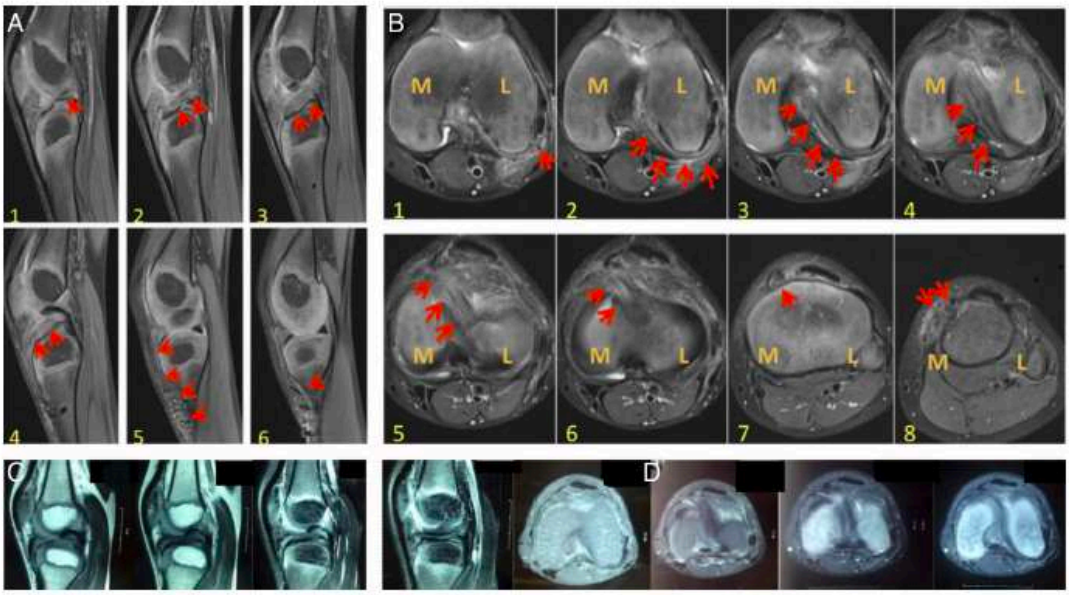


Figure 6 MR of the left knee: Sagittal and axial views 6 (A and B) and 48 (C and D) months after surgery. Red arrow—ligament graft 6 months after surgery.

pain after physical activities and significant spontaneous joint subluxation leading to probable associated injuries were all considered, resulting in the decision for surgical extra-articular ligament reconstruction using the patient's iliotibial band as a graft. For this unique case, the treatment decision was correct, since, even without anatomical ACL reconstruction, the patient had and excellent clinical outcome. Imaging studies and clinical evaluation controls 6 months and 4 years after surgery showed no more falls, no pain and no subluxation. No associated injuries in the knee were diagnosed, either. We believe that even for skeletally immature patients with an ACL tear, surgical ligament reconstruction should be considered.

Learning points

- Even in the younger patient with anterior cruciate ligament injury, the possibility of reconstruction to avoid future knee problems can be considered.
- There were no major complications 4 years after reconstruction of the patient's knee and leg.
- The functional results were satisfactory 4 years after reconstruction.
- There were no limitations in daily activities.

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Contributors DCA wrote and documented the case study. SC and AB examined and supplied the case data. MC was the orthopaedic surgeon who conducted the surgery.

Competing interests None declared.

Patient consent Obtained.

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12. CONGRESSOS COM APRESENTAÇÕES MAIS RELEVANTES REFERENTES AO TEMA

Sociedade Brasileira de Cirurgia do Joelho
MCMLXXXIII

CERTIFICADO

Dr. Diego da Costa Astur

Participou como debatedor do Caso Clínico" Lesão cruzado anterior em paciente com fise aberta", na Reunião Mensal da Sociedade Brasileira de Cirurgia do Joelho, realizada no dia 28 de março de 2019

São Paulo, 28 de março de 2019.

Dr. José Ricardo Pécora
Presidente da SBCJ

Dr. Riccardo Gobbi
Coordenador das Reuniões Científicas

ISAKOS

International Society of Arthroscopy, Knee Surgery & Orthopaedic Sports Medicine

Certifies that:

Diego C. Astur, MD, PhD
BRAZIL

for presenting the presentation titled

ACLR in Open Epiphyses / RLCA en Epífisis Abiertas

at the 12th Biennial ISAKOS Congress
May 12-16, 2019 • Cancun, MEXICO

Marc R. Safran, MD
ISAKOS President 2017-2019

INTERNATIONAL CHILD AND ADOLESCENT KNEE CONGRESS

CONVENERS

NICK NICOLAOU | FAZAL ALI | ADIL AJUIED

CERTIFICATE OF PARTICIPATION

I certify that

Prof Diego da Costa Astur

Participated as Faculty at the

International Child and Adolescent Knee Congress

held at Sheffield City Hall

on

Thursday 13th of June 2019

Friday 14th of June 2019

Content Delivered:

- *All Epiphyseal and Partial Transphyseal ACL reconstruction*
- *What happens to the graft with growth*
- *Revision ACL reconstruction in Children*

Mr Nicolas Nicolaou

Paediatric Knee Association

SBRATE2019
V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte

16 E 17 DE AGOSTO
WINDSOR BARRA | RIO DE JANEIRO | RJ

Certificamos que o trabalho

"ANTERIOR CRUCIATE LIGAMENT RE-RUPTURE IN PEDIATRIC POPULATION IS RELATED TO LOWER FUNCTIONAL SCORES AT RETURN TO ACTIVITY: A PROSPECTIVE, MID-TERM FOLLOW-UP STUDY"

do(s) autor(es): ***DIEGO COSTA ASTUR, CAMILA COHEN KALEKA, PEDRO DEBIEUX, JOSEPH J KROB, MOISES COHEN, JOÃO VICTOR NOVARETTI, ELTON LUIZ BORGES, EDUARDO VASCONCELOS FREITAS, ADILSON GOES***, foi apresentado no formato Oral durante o **V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte**, realizado dias 16 e 17 de gosto de 2019, no Hotel Windsor Barra no Rio de Janeiro – RJ.

Rio de Janeiro, 17 de agosto de 2019.

REALIZAÇÃO
SBRATE

Rodrigo Campos Paco Lasmar
Presidente SBRATE

João Alves Grangeiro Neto
Presidente CBRATE

Para verificar a autenticidade deste certificado, acesse o link http://sbrate2019.gnius.com.br/certificado e informe o código: 0901100077

SBRATE2019
V Congresso da Sociedade Brasileira de Artroscopia e Traumatologia do Esporte

16 E 17 DE AGOSTO
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Brazilian-UConn Symposium
September 10, 2019
5 pm – 7 pm

Location: UConn MSI 4th Floor

Attendees:

Katherine Coyner
Robert Arciero
Augustus Mazzocca
Cory Edgar
Kevin Shea
John Fulkerson
James Lee Pace
Elifho Obopilwe

3 Sports Fellows
2 Non Op Fellows
3 Sports Residents
2 German Fellows
3-5 Medical Students
4 Brazilian Surgeons
Research Resident

5:00 pm – 5:10 pm **Introduction**

5:10 pm – 5:25 pm **Andrew Jimenez, MD**
Meniscal Transplant case & literature review
Orthopaedic Sports Medicine Fellow

5:25 pm – 5:40 pm **João Novaretti, MD**
Meniscus overview

5:40 pm – 5:55 pm **Diego Astur, MD**
ACL in pediatric population

5:55 pm – 6:10 pm **Nathan Grimm, MD**
Multi-ligamentous Knee Recon & literature review
Orthopaedic Sports Medicine Fellow

6:10 pm – 6:25 pm **Ben Levy, MD**
Trochleoplasty Case & literature review
Orthopaedic Sports Medicine Fellow

6:25 pm – 6:40 pm **Lukas Muench, MD**
Mesenchymal stem cell reservoirs in the knee
Research Fellow

6:40 pm – 6:55 pm **Cory Edgar, MD PhD**
Large series of fresh OCA in PF compartment


ACL
tudy group
2020 BIENNIAL MEETING
KITZBÜHEL
AUSTRIA
SUNDAY, JANUARY 26TH thru
THURSDAY, JANUARY 30TH

SUNDAY, JANUARY 26

19:00 - 21:00 Welcome Reception/ Registration at Hotel Rasmushof

MONDAY, JANUARY 27

06:00 - 06:30 BREAKFAST

06:30 - 06:45 WELCOME - Christopher Kaeding | John Bergfeld | Christian Fink | Christian Hoser | Volker Musahl | Karl Peter Benedetto

MODERATORS - Andrew Amis | Carl Imhauser
BASIC SCIENCE

06:45 - 06:52 *Sandro Fucentese (Guest of Peter Burkart)*
(1) Randomized Controlled Trial of an Osteoconductive Scaffold Positioned to Augment Graft Incorporation after ACL-Reconstruction - Interim Analysis

06:53 - 07:03 Andrew Amis
(2) Should We Cut The ACL In Lab Experiments Or Should It Be Ruptured Traumatically?

07:04 - 07:11 Mirco Herbort
(3) The "Bankart Knee": Biomechanical Consequences Of A Posterolateral Tibia Plateau Impression Fracture As Concomitant Injury Of ACL Rupture

07:12 - 07:19 Jason Koh
(4) Does The ACL Fail Through Attrition? Subfailure Impingement Of The Native Rat ACL Results In Biomechanical Changes And Cell Death.

07:20 - 07:27 David McAllister
(5) Cyclic Testing Of Soft Tissue Grafts For ACL Reconstruction

07:28 - 07:35 Marc Safran
(6) Is There Really A Relationship Between Femoroacetabular Impingement And The Anterior Cruciate Ligament

07:36 - 07:43 Amelie Stoehr
(7) Histological And Immunohistochemical Differences In Remodeling Of Human ACL Grafts

07:44 - 07:51 *Niv Marom (Guest of Andrew Pearle)*
(8) Forces And Torques Of The Pivot Shift (PS)

07:52 - 07:59 *Florian Imhoff (Guest of Hermann Mayr)*
(9) The Effect Of Slope And Varus Correction High Tibial Osteotomy In An ACL-Deficient Und ACL-Reconstructed Knee – A Biomechanical

08:00 - 08:20 DISCUSSION

08:20 - 08:35 BREAK

MODERATORS - Julian Feller | Jacques Menetrey
ACL AND MENISCUS

08:35 - 08:42 Karl Eriksson
(10) Meniscus Transplant/Substitution Using Autologous Tendon Graft. Early Experiences From First 5 Cases In A Prospective Pilot Study

08:43 - 08:50 Elmar Herbst
(11) Distraction Forces On The Meniscal Roots Depend On Axial Loading Rather Than Flexion Angle

08:51 - 08:58 (12) ACL & Meniscus ACC Rehab Thomas Klootwyk

08:59 - 09:06 James Robinson
(13) Concomitant Repair Of Displaced Bucket Handle Repairs And ACL Reconstruction

09:07 - 09:14 Romain Seil
(14) High Incidence Of Previously Neglected Meniscus Lesions Influencing Knee Biomechanics In Association With ACL Injuries.

09:15 - 09:23 Tim Spalding
(15) Results Of Primary And Revision ACL Reconstruction With Meniscal Transplant: Good Results In Selected Patients

09:24 - 09:31 Renee Verdonk
(16) A Polyurethane Partial Meniscal Implant For Chronic Painful Partial Meniscectomy- A 5 Y+ Follow Up Evaluation

09:32 - 09:57 DISCUSSION

ADJOURN

15:30 - 16:00 SNACK

MODERATORS - Ryosuke Kuroda | Andrew Pearle
ANATOMIC ACL

16:00 - 16:07 Joan Monllau
(17) Selective Bundle Reconstruction In Partial ACL Tears Leads To Excellent Long-Term Functional Outcomes And A Low Percentage Of Failures

16:08 - 16:15 Atsuo Nakamae
(18) Improvement Of Proprioceptive Function After Anterior Cruciate Ligament Augmentation: Comparison With Single- And Double-Bundle Reconstruction

16:16 - 16:23 Konsei Shino
(19) Tunnel Location And Clinical Outcomes After The Anatomic Triple Bundle ACL Reconstruction With Hamstring Tendon Graft

16:24 - 16:31 Robert Smigielski
(20) Ribbon ACL Reconstruction Using Quad Tendon – The Preliminary Findings Of A Two-Year Follow-Up Including CT And MRI Scans

16:32 - 16:39 *Daniel Guenther (Guest of Volker Musahl)*
(21) Remnant Preserving Is Crucial To Improving Patient Outcomes After ACL Reconstruction

16:40 - 17:05 DISCUSSION

17:05 - 17:20 BREAK

MODERATORS - Andy Williams | Yuichi Hoshino
ACL INSTABILITY

17:20 - 17:27 *Lukas Willinger (Guest of Andrew Amis)*
(22) Attachment Points And Length Change Patterns Of The Medial Knee Structures

17:28 - 17:35 *Guido Wierer (Guest of Karl Peter Benedetto)*
(23) Anteromedial Instability Of The Knee

17:36 - 17:43 *Christoph Kittl (Guest of Christian Hoser)*
(24) Anteromedial Rotatory Instability Of The Knee: Biomechanics And Related Reconstructions

17:44 - 17:51 Moises Cohen
(25) The Presence Of The Arthroscopic "Floating Meniscus" Sign As An Indicator For Surgical Intervention In Patients With Combined Anterior Cruciate Ligament And Grade II Medial Collateral Ligament Injury

17:52 - 17:59 *Kanto Nagai (Guest of Ryosuke Kuroda)*
(26) In Vivo ACL Bundle Elongation Shows Complex Change During Walking And Running: Analysis Using Biplane Radiography System

18:00 - 18:07 Julian Feller
(27) Is The Kira Device Useful In Quantifying The Pivot Shift

18:08 - 18:15 Yuichi Hoshino
(28) The Coalition Of Tibial Tunnels In Anatomic Double Bundle ACL Reconstruction, Does It Matter? Investigation Using An Electromagnetic Pivot-Shift Measurement.

18:16 - 18:41 DISCUSSION

ADJOURN

TUESDAY, JANUARY 28

06:00 - 06:30 BREAKFAST

MODERATOR - Constance Chu
ACL IMAGING

06:30 - 06:37 Daisuke Araki
(29) Different Cutting Planes For Evaluating Bone Tunnels Affect Accurate Tunnel Position Description In Anterior Cruciate Ligament Reconstruction.

06:38 - 06:45 Matteo Denti
(30) Anterior Cruciate Ligament Inclination Angles On The Coronal And Sagittal Planes After Reconstructions By Different Techniques

06:46 - 06:53 David Flanigan
(31) Correlation Of PET MR Imaging In ACL Surgery With Tunnel Widening

06:54 - 07:01 Jacques Menetrey
(32) Isolated Anterior Cruciate Ligament Injury Could Be Much Less Common Than Conventional Wisdom

07:02 - 07:17 DISCUSSION

MODERATORS - Romain Seil | Stefano Zaffagnini
ACL PEDIATRIC

07:17 - 07:24 *Diego Astur (Guest of Moises Cohen)*
(33) Anterior Cruciate Ligament Re-Rupture In Pediatric Population Is Related To Lower Functional Scores At Return To Activity: A Prospective, Mid-Term Follow-Up Study

07:25 - 07:32 Mary Lloyd Ireland
(34) Secondary Injuries More Prevalent For Females Following Pediatric ACL Reconstruction: A Systematic Review

07:33 - 07:40 Walter Lowe
(35) Anterior Cruciate Ligament Reconstruction With Quadriceps Tendon Autograft In Skeletally Immature Adolescents

07:41 - 07:56 DISCUSSION

MODERATORS - Karl Ericksson | Mary Lloyd Ireland
ACL TIMING

07:56 - 08:03 Bjorn Barenius
(36) Early Results Of Treating ACL Ruptures With A Dynamic Brace

08:04 - 08:12 Christopher Kaeding
(37) Using A Risk Calculator In ACL Reconstruction Decision Making

08:13 - 08:20 Eiji Kondo
(38) Impact Of The Surgical Timing On The Clinical Outcome In Anatomic Double-Bundle Anterior Cruciate Ligament Reconstruction Using Hamstring Tendon Autografts

08:21 - 08:36 DISCUSSION

08:36 - 08:51 BREAK

MODERATORS - Bertrand sonnery-Cottet | Alan Getgood
ACL ANTEROLATERAL

08:51 - 08:58 *Camlio Helito (Guest of Christopher Kaeding)*
(39) Combined Reconstruction Of The Anterolateral Ligament In Patients With ACL Injury And Ligamentous Hyperlaxity Leads To Better Clinical Stability And A Lower Failure Rate Than Isolated ACL Reconstruction

08:57 - 09:02 *Joao Novaretti (Guest of John Bergfeld)*
(40) Does Lateral Extra-Articular Tenodesis Of The Knee Affect ACL Graft In-Situ Forces And Tibiofemoral Contact Pressures?

09:03 - 09:08 Brian Devitt
(41) Radiological Identification Of Injury To The Kaplan Fibers Of The Iliotibial Band

09:09 - 09:14 Alan Getgood
(42) Predictors Of Poor Outcome Following ACL Reconstruction With Or Without Lateral Extra-Articular Tenodesis: The STABILITY Experience

09:15 - 09:20 Danyal Nawabi
(43) The Effect Of Lateral Extra-Articular Tenodesis (LET) On Anterior Cruciate Ligament Graft Forces And Knee Kinematics ACL Graft

09:21 - 09:26 Hideyuki Koga
(44) Contribution Of Additional Anterolateral Structure Augmentation To Controlling Pivot Shift In Anterior Cruciate Ligament Reconstruction Based On Objective Evaluation Of Pivot Shift Phenomenon Using Triaxial Accelerometer

09:27 - 09:32 Volker Musahl
(45) Clinical Biomechanics Of ACL Reconstruction With And Without Tenodesis

09:33 - 09:38 Carl Imhauser
(46) Engagement Of Lateral Extra-Articular Tenodesis (LET) And An

09:39 - 09:44 Andrew Pearle
(47) Impact Of Lateral Extraarticular Tenodesis (LET) On Tibiofemoral Contact Mechanics

09:45 - 09:50 *Nicolas Bouguenec (Guest of Philippe Colombet)*
(48) Combined Reconstruction Of ACL And ALL With Hamstrings According To A Current Technique: What Is The Rate Of Osteoarthritis At 15 Years Of Mean Follow-Up

09:51 - 09:56 Brett Fritsch *(Guest of David Parker)*
(49) A Kinematic And Contact Pressure Analysis Of Commonly Used Anterolateral Procedures In Combination With Anterior Cruciate Ligament Reconstruction

09:57 - 10:17 DISCUSSION

ADJOURN

15:30 - 16:00 SNACK

16:00 - 17:00 FIRST BUSINESS MEETING

MODERATORS - Christian Fink | Martin Lind
ACL QUADRICEPS TENDON

17:00 - 17:07 *Marc Strauss (Guest of Christian Fink)*
(50) Qualitative And Quantitative Anatomy Of The Human Quadriceps Tendon

17:08 - 17:15 Christian Fink
(51) Revision Rates Following ACL Reconstruction With Quadriceps Tendon Vs. Hamstring Grafts – Influence Of Age, Sex And Sports Activity

17:16 - 17:23 Christian Hoser
(52) Comparison Of Hamstring And Quadriceps Tendon Autografts In ACL Reconstruction: A Prospective "Patient-Reported-Outcome-Measurement" (PROM) Study On 551 Patients

17:24 - 17:31 Martin Lind
(53) Increased Revisions Of Quadriceps Tendon Autografts Compared To Other Autografts Used For Anterior Cruciate Ligament Reconstruction. Results From The Danish Knee Ligament Registry.

17:32 - 17:39 Seth Sherman
(54) Comparison Of Bone-Patella Tendon-Bone (BTB) And Quadriceps Autograft For ACL Reconstruction In Patients Under 18 Years Of Age