


A Prospective, Randomized Comparison of Traditional and Accelerated Approaches to Postoperative Rehabilitation following Autologous Chondrocyte Implantation: 2-Year Clinical Outcomes

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Abstract

Objective: To determine the safety and efficacy of “accelerated” postoperative load-bearing rehabilitation following matrix-induced autologous chondrocyte implantation (MACI). **Design:** A randomized controlled study design was used to investigate clinical outcomes in 70 patients following MACI, in conjunction with either accelerated or traditional approaches to postoperative weight-bearing (WB) rehabilitation. Both interventions sought to protect the implant for an initial period and then incrementally increase WB. Under the accelerated protocol, patients reached full WB at 8 weeks postsurgery, compared to 11 weeks for the traditional group. Clinical outcomes were assessed presurgery and at 3, 6, 12, and 24 months postsurgery. **Results:** A significant effect ($P < 0.017$) for time existed for all clinical measures, demonstrating improvement up to 24 months in both groups. A significant interaction effect ($P < 0.017$) existed for pain severity and the 6-minute walk test, with accelerated group patients reporting significantly less severe pain and demonstrating superior 6-minute walk distance over the period. Although there was a significant group effect ($P < 0.017$) for maximal active knee extension range in favor of the accelerated regime, no further significant differences existed. There was no incidence of graft delamination up to 24 months that resulted directly from the 3-month postoperative rehabilitation program. **Conclusion:** The accelerated load-bearing approach that reduced the length of time spent ambulating on crutches produced comparable if not superior clinical outcomes up to 24 months postsurgery in the accelerated rehabilitation group, without compromising graft integrity. This accelerated regime is safe and effective and demonstrates a faster return to normal function postsurgery.

Keywords

matrix-induced autologous chondrocyte implantation (MACI), partial weight bearing (PWB), rehabilitation, gait

Introduction

Autologous chondrocyte implantation (ACI) has become an established technique for the repair of full-thickness chondral defects in the knee.¹ It is a 2-stage procedure with an initial harvest of healthy cartilage, isolation and expansion of chondrocytes *ex vivo*, and subsequent reimplantation of cells into the chondral defect. Traditional ACI techniques required the injection of cells under a periosteal (PACI)² or biodegradable collagen (CACI)³ membrane that was sutured to the adjacent healthy cartilage walls. These techniques have proven to be surgically complex and may result in extensive micro-trauma and cell leakage,⁴ as well as further problems associated with

the use of periosteum.¹ More recently, matrix-induced autologous chondrocyte implantation (MACI) has attempted to overcome these drawbacks by seeding chondrocytes directly onto a type I/III collagen membrane and fixing it

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to the underlying subchondral bone with fibrin glue, which has been shown to support migration and proliferation of human chondrocytes.^{5,6}

Robertson *et al.*⁷ have previously proposed 4 main factors that influence patient outcome and quality of repair tissue following MACI: (1) successful cell culturing, (2) efficiency of the surgical procedure, (3) patient cooperation in all aspects of the pre- and postoperative program, and (4) timely progression of load bearing and postoperative rehabilitation. Although the postoperative mechanical environment is known to play an essential role in both graft protection and chondrocyte differentiation and development⁸ following MACI, best patient outcome at present seems limited by a lack of knowledge on how best to progressively increase load bearing and exercise postsurgery.

To attain optimal cell proliferation and matrix synthesis postsurgery, research supports the need for dynamic⁹ and shear¹⁰ loads, as opposed to static compression¹¹ and immobilization.¹² Therefore, a graded program incorporating controlled exercise and progressive partial weight bearing (PWB) is recommended following the general ACI procedure,^{13,14} although the most optimal postoperative weight-bearing (WB) program remains to be determined. Traditionally, postoperative rehabilitation programs incorporating progressive PWB have been conservative for PACI¹⁵ and CACI,⁷ in order to protect the graft. However, when compared to traditional ACI procedures, MACI removes a number of structurally and functionally debilitating side effects associated with the previous surgical techniques.^{1,16} Therefore, we presented an accelerated MACI rehabilitation protocol¹³ that demonstrated tolerance by both the patient and the graft to loading throughout the return to full WB over a 3-month period from surgery. Compared to a traditionally “conservative” return to full WB, the accelerated rehabilitation regime resulted in less pain and fewer symptoms and a faster return to normal function in the early postoperative stages.

In this article, we present 24-month clinical outcomes in patients who have undergone a randomized allocation to either conservative or accelerated approaches to postoperative WB rehabilitation. We hypothesized that there would be no significant differences in subjective or functional outcomes in MACI patients up to 24 months postsurgery when comparing these differing rehabilitation regimes. Furthermore, we hypothesized that there would be no differences in graft delamination rates directly as a result of either approach to postoperative rehabilitation.

Methods

Participants

A block randomization procedure (gender; age less or greater than 40 years) was used to allocate 70 patients

Table 1. Descriptive Parameters for the Accelerated and Traditional Rehabilitation Groups

	Accelerated	Traditional
Number of patients	34	36
Gender (M/W), n	22/12	23/13
Age, y (range)	36.6 (21-62)	39.8 (16-63)
10-19	0	2
20-29	9	8
30-39	13	12
40-49	8	8
50-59	3	4
60-69	1	2
Defect location (MFC/LFC)	26/8	26/10
Defect size, cm ² (range)	3.22 (0.65-10.00)	3.31 (0.75-10.00)
Prior procedures, n (range)	1.2 (0-3)	1.4 (0-4)

M, men; W, women; MFC, medial femoral condyle; LFC, lateral femoral condyle.

(47 men, 23 women) to either traditional or accelerated rehabilitation pathways (**Table 1**), and all but 1 patient was retained up until 24 months postsurgery (motor vehicle accident resulting in death at 3 months postsurgery and subsequent exclusion from the study analysis) (**Fig. 1**). Only patients who underwent MACI to localized, full-thickness medial or lateral femoral condylar defects to the knee participated in this study. The sample sizes used were based on an *a priori* power calculation that showed at least 22 subjects in each of the 2 groups were required to reveal differences at the 5% significance level, with 80% power.

The MACI Technique

The surgical technique has been described previously.¹³ Initially, an arthroscopic surgery was performed to harvest normal articular cartilage from a non-WB area of the knee, at which time healthy chondrocytes were isolated, cultured, and seeded onto a type I/III collagen membrane (ACI-Maix Matricel GmbH, Herzogenrath, Germany) *ex vivo* over a 6- to 8-week period. During second-stage implantation, care was taken to prepare the chondral defect by removing all damaged cartilage down to, but not through, the subchondral plate. The MACI membrane was pressed into the defect and secured using a thin layer of fibrin glue.

Traditional and Accelerated Rehabilitation Protocols

Immediate postoperative inpatient rehabilitation consisted of continuous passive motion (0-30 degrees) within 12 to 24 hours after surgery to reduce the chance of intra-articular adhesions¹⁷; active dorsi- and plantar-flexion of the ankle

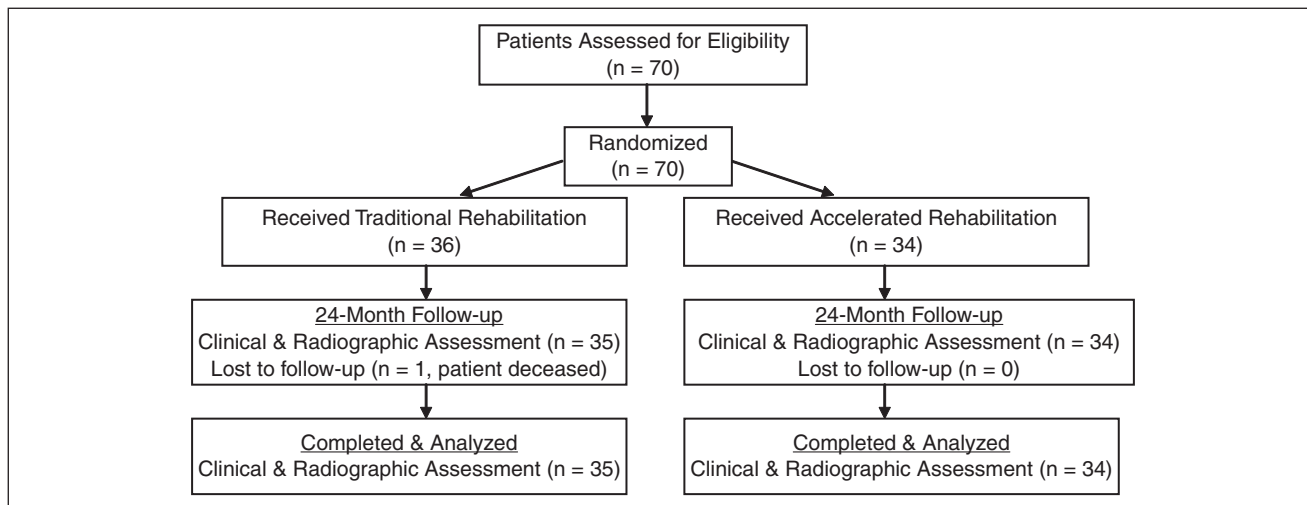


Figure 1. Patient randomization and assessment throughout the trial.

Table 2. Load-Bearing Gradients Followed by Patients with Matrix-Induced Autologous Chondrocyte Implantation in the Traditional and Accelerated Rehabilitation Groups

Weeks Postsurgery	2	3	4	5	6	7	8	9	10	11	12
Traditional group											
Weight bearing, %BW		≤20			50	60	70	80	90		100
Crutches, n		2			1	1	1	1	1	1	0
Brace		Y			Y	Y	Y	Y	Y	Y	N
Accelerated Group											
Weight bearing, %BW	≤20	30	40	50	60	80		100			
Crutches, n	2	2	2	2	1	1	1	0			
Brace	Y	Y	Y	Y	Y	Y	Y	N			

BW, body weight.

to encourage lower extremity circulation; isometric contraction of the quadriceps, hamstrings, and gluteal musculature to maintain muscle tone and minimize muscle loss^{2,17}; cryotherapy to control edema and; teaching of proficient toe-touch ambulation through the affected limb. To protect the repaired cartilage surface, a range-of-motion control brace was worn postoperatively for 24 hours per day, depending on the stage of rehabilitation (**Table 2**).

Following these early postoperative stages, patients were enrolled into either a traditional (conservative) or accelerated load-bearing rehabilitation protocol¹³ (**Table 2**). The traditional protocol consisted of a 5-week period of WB at 20% body weight (BW), followed by a progressive increase to full WB at 11 weeks postsurgery (**Table 2**). The accelerated protocol consisted of a 2-week period of WB at 20% BW for early graft protection, with a progressive increase to full WB at 8 weeks postsurgery. Patients wore a protective knee brace and used a single crutch, 2 crutches, or no walking aids depending on the stage of rehabilitation (**Table 2**). The bathroom scale method was used to teach patients the WB restriction.^{14,18}

Clinical Assessment

Three subjective questionnaires were used to evaluate patient outcome presurgery and at 3, 6, 12, and 24 months postsurgery in all 70 patients. These included (1) the Knee Injury and Osteoarthritis Outcome Score (KOOS)¹⁹ to assess knee pain, symptoms, activities of daily living (ADLs), sport and recreation, and knee-related quality of life (QOL); (2) the Visual Analog Scale (VAS) to assess the frequency (VAS-F) and severity (VAS-S) of knee pain on a scale of 0 to 10; and (3) the Short Form Health Survey (SF-36), which evaluated the general health of the patient, producing a mental (MCS) and physical component score (PCS).²⁰

Three functional capacity tests were administered to evaluate patient outcome presurgery and at 3, 6, 12, and 24 months postsurgery: (1) maximal active knee flexion and extension range, (2) the 6-minute walk test^{13,21} to assess the maximum comfortable distance the patient could walk in a 6-minute time period, and (3) activity level using an activity monitor (Actigraph, MTI Health Services, Ft. Walton Beach, FL) to assess the total number of steps

taken over a 7-day period. Patients were instructed to attach the monitors as soon as they got out of bed each morning, remove and reattach them before and after each shower, and then remove them before bed each night. Activity monitor data were processed with ActiSoft Analysis Software (Actigraph, ActiSoft Analysis Software, Version 3.2.6, MTI Health Services). Not all patients could be assessed preoperatively, and for this reason, only 48 patients had a complete history of pre- and postoperative data for analysis (24 accelerated; 24 traditional). Furthermore, activity level was only assessed at 3, 6, and 12 months postsurgery in 51 patients (24 accelerated; 27 traditional).

Magnetic Resonance Imaging Assessment

High-resolution magnetic resonance imaging (MRI) was used to assess graft adherence at 3, 12, and 24 months postsurgery. Scans were performed using a Siemens Symphony 1.5 T scanner (Siemens, Erlangen, Germany). Normal T1, T2, and cartilage-specific echo sequences were obtained in coronal and sagittal planes (repetition time [TR] = 3100 ms; echo time [TE] = 32 ms; field of view = 14 cm; slice thickness = 3.0 mm; matrix 384 × 224/256 × 192; acquisition = 2). An independent, experienced musculoskeletal radiologist was enlisted to determine whether the graft was attached or had been delaminated (subchondral bone exposed, complete delamination, or dislocation and/or loose body).

Statistical Analysis

Statistical analysis was performed using SPSS software (Version 17.0; SPSS, an IBM Company). A series of repeated-measures analyses of variance (ANOVAs) were used to investigate the progression of subjective and functional outcome measures between the accelerated and traditional patient groups, and in the occurrence of significant main or interaction effects, independent *t* tests were used to investigate differences in the dependent variable between the specific assessment time points. To adjust for these multiple comparisons, a full Bonferroni correction was not used because this method is too conservative, so statistical significance for the ANOVA and *t* test calculations was determined at $P < 0.017$ (i.e., 0.05/3).^{18,22}

Results

There was no significant difference in any of the patient or defect descriptive parameters between the 2 groups presurgery (**Table 3**).

Subjective Assessment

There was a significant time effect ($P < 0.017$) for all subjective measures, whereas there was no significant

Table 3. Presurgery Descriptive Statistics: Mean (SE)

Variable	Accelerated	Traditional	P Value
Age, y	36.6 (1.9)	39.7 (2.3)	0.304
Weight, kg	79.0 (1.8)	83.8 (2.4)	0.120
Height, m	1.74 (0.02)	1.74 (0.02)	0.948
Defect size, cm ²	3.22 (0.45)	3.31 (0.49)	0.891

group effect ($P > 0.017$) across the pre- and postoperative timeline (**Table 4**). A significant interaction effect ($P > 0.017$) existed only for the VAS-S (**Table 4** and **Fig. 2**). Independent *t* tests demonstrated a significantly lower ($P > 0.017$) pain severity (VAS-S) in the accelerated group at 3, 6, and 12 months postsurgery when compared with the traditional group.

Functional Assessment

There was a significant time effect ($P < 0.017$) for all functional measures across the pre- and postoperative timeline, and there was a significant group effect ($P < 0.017$) for maximal active knee extension range (**Table 5**). A significant interaction effect ($P > 0.017$) existed for the 6-minute walk test (**Table 5** and **Fig. 3**). Independent *t* tests demonstrated a significantly better ($P > 0.017$) 6-minute walk score in the accelerated group at 3, 6, and 24 months postsurgery when compared with the traditional group. No significant interaction effects existed for the other functional variables, although independent *t* tests demonstrated a significantly lower ($P < 0.017$) active knee extension range in the accelerated group at 12 and 24 months postsurgery when compared with the traditional group.

MRI Assessment

There was no incidence of graft delamination at 3 months postsurgery across all patients, as assessed by MRI and previously reported.¹³ There was 1 incidence of graft delamination between 6 and 9 months postsurgery in a patient who underwent the accelerated rehabilitation pathway, although this was not related to the initial 3-month rehabilitation program. Clinical scores for this patient were retained in the analysis, although the patient remains closely monitored to ascertain whether further surgical intervention may be necessary in the future. There was no further incidence of graft delamination up until and including the 24-month time point.

Discussion

Although surgical and cell culturing methods have evolved significantly since the inception of the general ACI procedure, current postoperative WB rehabilitation protocols remain relatively conservative and are based on theoretical

Table 4. Summary of Mean (SE) Pre- and Postoperative Subjective Results for the Accelerated (Acc) and Traditional (Trad) Groups

Variable	KOOS (Pain)	KOOS (Symp)	KOOS (ADL)	KOOS (SR)	KOOS (QOL)	SF-36 (PCS)	SF-36 (MCS)	VAS (Freq)	VAS (Sev)
Acc (pre-op)	69.81 (3.21)	74.52 (3.24)	81.94 (3.18)	29.42 (4.67)	36.98 (4.10)	41.47 (1.66)	51.17 (1.83)	4.77 (0.50)	4.55 (0.45)
Trad (pre-op)	67.87 (3.21)	68.57 (3.24)	76.85 (3.18)	22.75 (4.67)	29.68 (4.10)	37.11 (1.66)	52.33 (1.83)	5.39 (0.50)	4.35 (0.45)
Acc (3 mo)	79.16 (2.85)	83.39 (2.45)	83.43 (2.41)	11.75 (3.08)	37.02 (3.55)	37.08 (1.48)	54.54 (1.68)	2.67 (0.51)	2.17 (0.33)
Trad (3 mo)	69.26 (2.85)	75.15 (2.45)	78.28 (2.41)	6.83 (3.08)	34.38 (3.55)	35.01 (1.48)	56.16 (1.68)	4.28 (0.51)	3.35 (0.33)
Acc (6 mo)	80.93 (2.97)	86.13 (2.54)	88.46 (2.34)	24.33 (4.48)	44.28 (3.79)	43.49 (1.65)	55.71 (1.32)	2.60 (0.52)	1.95 (0.32)
Trad (6 mo)	76.82 (2.97)	80.42 (2.54)	84.39 (2.34)	26.00 (4.48)	42.02 (3.79)	41.94 (1.65)	56.12 (1.32)	4.40 (0.52)	3.05 (0.32)
Acc (12 mo)	84.68 (2.99)	83.27 (3.15)	92.22 (2.35)	39.83 (5.60)	50.73 (4.04)	47.59 (1.69)	55.69 (1.48)	2.39 (0.52)	1.78 (0.33)
Trad (12 mo)	80.46 (2.99)	81.01 (3.15)	88.65 (2.35)	46.50 (5.60)	49.69 (4.04)	44.57 (1.69)	55.13 (1.48)	3.33 (0.52)	2.86 (0.33)
Acc (24 mo)	86.15 (2.82)	88.04 (2.59)	92.79 (2.36)	61.17 (5.80)	59.59 (4.33)	49.79 (1.80)	55.95 (1.07)	2.15 (0.46)	1.97 (0.33)
Trad (24 mo)	82.50 (2.82)	82.86 (2.59)	90.32 (2.36)	55.00 (5.80)	58.75 (4.33)	47.02 (1.80)	56.11 (1.07)	2.86 (0.46)	2.48 (0.33)
Time effect (P value)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.001	<0.0001	<0.0001
Group effect (P value)	0.148	0.058	0.141	0.695	0.530	0.125	0.719	0.070	0.630
Interaction effect (P value)	0.846	0.758	0.509	0.334	0.757	0.808	0.887	0.363	0.013

Symp, symptoms; ADL, activities of daily living; SR, sport and recreation; QOL, quality of life; PCS, physical component score; MCS, mental component score; VAS, Visual Analog Scale; KOOS, Knee Injury and Osteoarthritis Outcome Score; SF-36, Short Form Health Survey; Freq, frequency; Sev, severity.

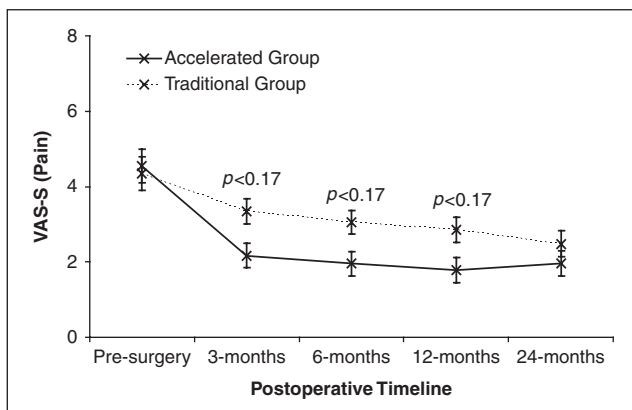


Figure 2. Changes in pain severity for the accelerated and traditional patient groups, throughout the pre- and postoperative timeline.

loading models and traditional ACI techniques. This is despite good rehabilitation following ACI being considered very important in both short- and long-term patient and graft outcomes.^{14,23} We have previously proposed an accelerated WB protocol¹³ that was designed to account for advancements in the surgical technique while still providing a safe return to normal physical function. This article presents a randomized comparison of differing postoperative WB rehabilitation protocols following MACI and seeks to determine the safety and efficacy of this accelerated WB regime compared with the traditionally conservative protocol.

A significant improvement in all subscales of the KOOS, SF-36, and VAS was demonstrated over the 24-month assessment period, indicated by a significant time effect ($P < 0.017$) for all subjective variables (**Table 4**). There were no significant differences ($P < 0.017$) between the 2 groups in reported subjective scores at baseline ($P > 0.05$), and although the accelerated group reported significantly less pain and symptoms at 3 months as previously reported,¹³ there were no further significant differences between 6 and 24 months. The accelerated group did, however, report significantly less severe pain over the assessment period when compared with the traditional group, as indicated by a significant interaction effect ($P < 0.017$; **Table 4** and **Fig. 2**).

Although the sport and recreation subscale of the KOOS significantly deteriorated in both groups from presurgery to 3 months as previously reported,¹³ largely as a result of the physical limitations imposed on patients at this point in the postoperative timeline,^{7,14} it was significantly better ($P < 0.017$) in both groups at 12 and 24 months postsurgery (**Table 4**). Furthermore, patients in both rehabilitation groups reported better scores for pain, symptoms, ADLs, and sports and recreation at 12 and 24 months postsurgery, as indicated by the KOOS subscales, when compared with those reported previously for both CACI²¹ and MACI²⁴ patients at 24 months postsurgery. Patients were asked to

answer all subjective questionnaires truthfully and to the best of their ability, although the degree of potential bias resulting from patient knowledge of their own treatment protocol in subjective reporting in the early postoperative stages remains unknown.

A significant improvement in all functional scores was observed over the 24-month period, indicated by a significant time effect ($P < 0.017$) for all functional variables (**Table 5**). There were no significant differences ($P < 0.017$) between the 2 groups in observed functional scores at baseline ($P > 0.05$), and although the accelerated group demonstrated a significantly higher level of general activity at 3 months postsurgery as previously reported,¹³ there were no further significant differences in activity between 6 and 12 months. However, the accelerated group demonstrated a significantly better 6-minute walk test over the assessment period when compared with the traditional group, as indicated by a significant interaction effect ($P < 0.017$; **Table 5** and **Fig. 3**). Although the observed scores at 12 and 24 months in the accelerated group were higher than those previously reported in CACI patients at 24 months postsurgery,²¹ the scores for the traditional group at the same time points remained slightly lower. The 6-minute walk test has been previously reported as a key component of many activities of normal daily living, as well as a foundation for functional independence.²¹

Furthermore, the accelerated group demonstrated a significantly lower ($P < 0.017$) active knee extension range at 12 and 24 months postsurgery when compared with the traditional group. Both groups were unable to demonstrate full knee extension presurgery, which was maintained at 3 months postsurgery (**Table 5**). However, although the accelerated group presented with a mild active hyperextension of the knee at 6 months and maintained this through to 24 months, the traditional group was unable to recover active full knee extension up until and including the 24-month time point (**Table 5**). It is unknown whether this was the result of the earlier knee mobilization under full WB as provided within the accelerated regime, although full active knee extension range is an important functional variable to recover postsurgery, particularly in allowing the return to a normal gait pattern.

As previously reported,¹³ there was no incidence of graft delamination at 3 months postsurgery, as assessed by MRI, or any up until the 24-month assessment time point that occurred directly as a result of the 2 rehabilitation interventions. There was, however, 1 incidence of graft delamination at approximately 9 months postsurgery. The cause of graft loss remains unknown but thought to be related to this patient's intensive work practices and increase in BW throughout this period. Interestingly, graft infill at 3 months postsurgery for this patient was classified as "full," approximating the height of the adjacent native cartilage. Graft delamination generally presents within the first 6 months and is reported in approximately 5% of

Table 5. Summary of Mean (SE) Pre- and Postoperative Functional Results for Accelerated (Acc) and Traditional (Trad) Groups

Variable	Six-Minute Walk Distance, m	Maximal Knee Flexion, Degrees	Maximal Knee Extension, Degrees	Activity, Steps/d
Acc (pre-op)	556.8 (20.49)	135.4 (2.3)	0.4 (0.4)	NA
Trad (pre-op)	528.2 (20.49)	128.5 (2.4)	0.7 (0.4)	NA
Acc (3 mo)	536.6 (22.6)	132.8 (3.3)	0.3 (0.5)	9932 (437)
Trad (3 mo)	449.5 (22.6)	123.6 (3.4)	1.2 (0.5)	8884 (412)
Acc (6 mo)	591.9 (21.4)	139.1 (2.1)	-0.3 (0.3)	10,633 (609)
Trad (6 mo)	545.3 (21.4)	134.9 (2.1)	0.8 (0.4)	10,590 (574)
Acc (12 mo)	620.0 (21.6)	142.5 (1.8)	-0.5 (0.2)	11,819 (658)
Trad (12 mo)	545.3 (21.6)	139.8 (1.8)	0.7 (0.2)	10,279 (620)
Acc (24 mo)	661.5 (20.1)	143.6 (1.58)	-0.7 (0.2)	NA
Trad (24 mo)	580.7 (20.1)	139.5 (1.6)	0.1 (0.2)	NA
Time effect (<i>P</i> value)	<0.0001	<0.0001	0.002	<0.0001
Group effect (<i>P</i> value)	0.043	0.054	0.015	0.183
Interaction effect (<i>P</i> value)	0.015	0.166	0.592	0.156

NA, not applicable.

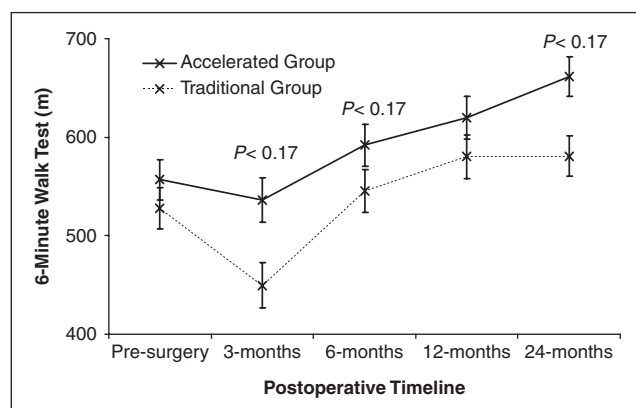


Figure 3. Changes in 6-minute walk distance (m) for the accelerated and traditional patient groups, throughout the pre- and postoperative timeline.

patients.¹⁵ Although this delamination was not related to the initial 3-month rehabilitation program, this incident does highlight the importance of structured and controlled activity through to full graft maturation, as well as maintenance of a healthy body weight. Determination of absolute graft failure coincided with complete delamination of the implanted graft and therefore its inability to withstand the dynamic forces (compressive and shear) placed on it during the return to full WB.

Our first hypothesis was not supported, whereby the accelerated group exhibited some superior subjective and functional outcomes, when compared with the traditional group. In summary, a significant group effect existed for active knee extension range in favor of the accelerated group, whereas patients who underwent the accelerated rehabilitation regime reported significantly less severe pain and demonstrated a superior 6-minute walk distance over the 24-month assessment period. Our second

hypothesis was supported, whereby there was no difference in graft delamination rates resulting directly from either approach to postoperative WB rehabilitation.

Protection and progressive stimulation of the implanted cells are the focus of the exercise rehabilitation program following MACI so that the best development and differentiation of the chondrocytes can occur. However, despite the majority of surgeons and therapists agreeing that postoperative rehabilitation is a critical component in achieving best patient outcome (ICRS—International Cartilage Repair Society Survey, Rehabilitation after Cartilage Repair, 2006), only limited, quality, randomized controlled trials in the area of rehabilitation following MACI have been published.¹³ Clinically, an excessively “aggressive” approach may risk graft delamination, whereas a too “conservative” approach may not provide adequate biomechanical graft stimulus while promoting excessive muscle atrophy and gait abnormalities, contributing to a poorer outcome.

Although long-term follow-up of this patient cohort is required to determine if there are any detrimental effects that may later emerge as a result of the accelerated protocol, the outcomes of this randomized trial demonstrate not only a safe and effective accelerated rehabilitation protocol but also a regime that provides several superior clinical outcomes to patients. Furthermore, this accelerated regime should reduce rehabilitation time and costs for the patient while providing a faster return to normal physical function.

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Declaration of Conflicting Interests

All authors have no other financial or personal relationships with other people and/or organizations that could inappropriately influence (bias) this work, in addition to the funding sources outlined in the acknowledgments.

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