

ARTICULAR CARTILAGE DEFECTS IN THE KNEE

POSTOPERATIVE REHABILITATION

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Focal articular cartilage defects in the knee joint are highly prevalent and are a common cause of functional restrictions and pain during daily life and sport activities^{1,2,3}. Treatment of these defects presents a clinical challenge for physicians and physiotherapists for two reasons. Firstly, this type of articular cartilage defect typically affects young active individuals in their mid-twenties to late thirties, who have high demands on their knee function. These individuals may be active sports participants and/or have an active or strenuous job⁴. Secondly, the nature of articular cartilage tissue – being avascular and aneural – prevents the physiological inflammatory response to tissue injury. This results in a repair tissue that is both qualitatively and quantitatively insufficient and incapable of meeting the demands of these active individuals⁵.

To address focal cartilage lesions in the knee, reparative and restorative surgical

treatment techniques are preferred. These techniques can be summarised by the term ‘cartilage repair’, as these techniques emphasise stimulation of the healing process in repair tissue. The most common techniques include microfracture, osteochondral grafts and autologous chondrocyte implantation (ACI)^{6,7}.

Surgeons and physiotherapists generally agree that rehabilitation after cartilage repair in the knee is critically important, with the potential to influence both patient outcome and the quality of repair tissue^{8,9}. However, good quality research to support these assumptions is lacking, with most of the rationale for rehabilitation after cartilage repair based on expert opinion, applied biomechanics and basic science⁹⁻¹⁶. Ideally, physiotherapists should implement an effective and individualised, but safe rehabilitation protocol that is built on evidence-based research and science⁸. This article will describe the

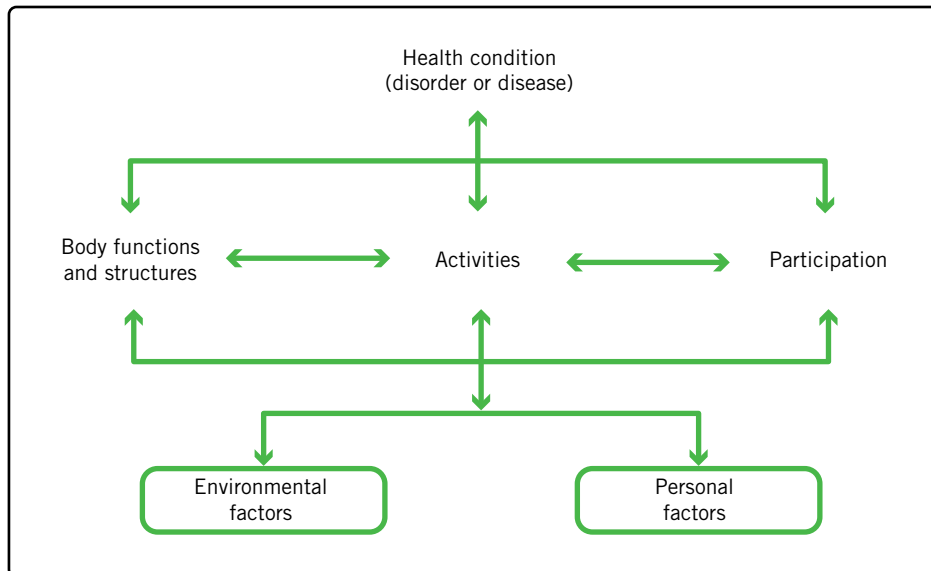
fundamental principles of postoperative rehabilitation after cartilage repair and will present the most important components of rehabilitation protocols after cartilage repair in the knee.

FUNDAMENTAL PRINCIPLES OF REHABILITATION

There are several factors which influence the quality of the repair tissue and patient outcomes, including: successful cell culturing under good practice conditions, expertise and technical proficiency of the surgeons, patient compliance to a pre- and postoperative treatment regime and a safe, but progressive, postoperative rehabilitation programme^{8,17}.

The World Health Organisation has established the International Statistical Classification of Diseases and Related Health Problems (ICF), which classifies health and health-related domains into several levels, including a list of body functions,

THE ICF MODEL: INTERACTION BETWEEN ICF COMPONENTS



DEFINITIONS

In the context of health:

- **Functioning** is an umbrella term for body functions, body structures, activities and participation. It denotes the positive aspects of the interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors).
- **Disability** is an umbrella term for impairments, activity limitations and participation restrictions. It denotes the negative aspects of the interaction between an individual (with a health condition) and that individual's contextual factors (environmental and personal factors).
- **Body functions** - the physiological functions of body systems (including psychological functions).
- **Body structures** - anatomical parts of the body such as organs, limbs and their components.
- **Impairments** - problems in body function and structure such as significant deviation or loss.
- **Activity** - the execution of a task or action by an individual.
- **Participation** - involvement in a life situation.
- **Activity limitations** - difficulties an individual may have in executing activities.
- **Participation restrictions** - problems an individual may experience in involvement in life situations.
- **Environmental factors** - the physical, social and attitudinal environment in which people live and conduct their lives. These are either barriers to or facilitators of the person's functioning.

body structures and a list of domains of activity and participation^{18,19}. Based on this classification, rehabilitation after cartilage repair aims to provide a mechanical environment for the local adaption and remodelling of the repair tissue (body functions and structures) and to restore joint range of motion (ROM) and muscle control (body functions). Further, it should be ensured that patients can safely return to an optimal level of knee function to perform activities such as walking and stair climbing (activities) to be able to participate safely in day to day activities, including working, social, recreational and sporting activities (participation).

A 'safe' return to activity requires a thorough understanding of the biological and biochemical factors that are inherent in the respective cartilage repair techniques. Further, the biomechanics of the affected joint needs to be considered to appreciate the forces that will be exerted on the defect area^{8,10}. Generally, an individual approach should be emphasised, addressing factors such as age, body mass index, number of previous surgeries, duration of symptoms and activity level^{8,9}.

TISSUE HEALING AND CONSEQUENCES FOR REHABILITATION

The process of rehabilitation after cartilage repair is guided by three biological healing phases independent of the inherent and specific differences between surgical cartilage repair procedures:

1. Initial protection and activation
2. Loading and functional restoration
3. Activity restoration⁹.

The first phase, protection and activation, is characterised by graft integration and stimulation of the chondrocytes. During the second phase, loading and functional restoration, matrix production is at its peak, with organisation of the collagen fibres. The focus of the third phase, activity restoration, is maturation and adaptation of the healing repair tissue^{9,20}.

The biological mechanism in the protection and activation phase differs

between the particular surgical techniques. With microfracture and ACI the cells contained in the defect start to differentiate and produce a soft and unorganised initial repair tissue, which is very vulnerable to mechanical overload and requires protection. Osteochondral grafting also needs protection to allow for an adequate bone-to-bone healing of the implanted grafts. As bony healing is less vulnerable to mechanical damage compared to cartilage growth, progression of weight bearing (WB) and WB activities in the protection and joint activation phase is usually faster with osteochondral grafting compared to microfracture and ACI. However, high shear and compressive forces in the first rehabilitation phase may negatively influence chondrocyte metabolic rate and tissue repair and integration of all three of these repair procedures. In contrast, low mechanical stimulus may support the development of cartilage tissue by promoting cartilage formation, nutrition and bone-to-bone healing. Hence, the challenge of the protection and joint activation phase is to provide appropriate stimulation of the healing tissue while avoiding deleterious forces which might jeopardise the healing process^{9,21,22}.

From a biological point of view, the aim of the loading and functional restoration phase is to increase the mechanical load to stimulate the chondrocytes' metabolism – leading to extracellular matrix (proteoglycans, collagen fibres) production. Mechanical load should be gradually increased to strengthen the healing tissue as it becomes more resilient to increased loading activities^{9,23}. However, the increase of mechanical stimulus and loading should be performed in a controlled and progressive manner to avoid excessive overload which might damage the healing tissue⁹.

The activity restoration phase is characterised by further organisation and maturation of the healing cartilage tissue with increased rigidity of the extracellular matrix due to further proteoglycan deposition, collagen production and cellular organisation^{7,24}. Gradually increased impact and sport-specific movement patterns prepare patients to return to the higher mechanical stress associated with sport activities⁹.

BIOMECHANICS

An understanding of applied clinical biomechanics and an appreciation of the forces that will be exerted on the healing tissue are essential in the design of rehabilitation programmes after cartilage repair. The contact area (distribution and magnitude), contact load and contact pressure during rehabilitation should be considered to minimise the danger of damaging the healing tissue and support the healing process by physiologically stimulating the tissue¹⁰. Therefore, information from the surgeon on the nature of the defect (size and location) is crucial. With this information, rehabilitation modalities and exercises can be incorporated in safe ranges, while avoiding ranges which might be detrimental to the healing tissue⁸.

The flexion and extension movement within the tibiofemoral joint is a combination of rolling and gliding of the surface of the femur and the tibia, combined with a rotational movement at the end of flexion and extension. To ensure a flexion and extension movement with a physiological load distribution on the cartilage surfaces, restriction of these rolling, gliding and rotational movements

should be avoided. During this extension and flexion only parts of the tibia and femur are articulating²⁵, thus, the load distribution in the tibiofemoral joint should be considered when progressing exercises. The tibiofemoral joint is exposed to high mechanical load during vertical WB activities (for example during walking, standing and stair climbing)²⁶, which should therefore be avoided in the early protection phase.

The patellofemoral joint is a sellar joint composed of the patella and the underlying femoral trochlea. This joint is stabilised by active and passive stabilisers; the major active stabiliser is the quadriceps muscle, whereas passive stabilisation is provided by the femoral condyle, the peripatellar retinaculum, and the medial and lateral patellofemoral ligaments^{26,27}. At higher knee flexion angles, particularly in WB positions, the load within the patellofemoral joint increases, implying increased loading of the healing cartilage tissue. However, near to extension, the load within the joint is low^{28,29}. Hence, WB activities with the knee in an extended position are possible without harming the repair tissue – a brace can be used to lock the knee in an extended position.

TABLE 1

Factors	Considerations/consequences
Age	Slower progression with increased age due to slower cartilage repair/regeneration
BMI	BMI > 30: slower and more gradual progression of rehabilitation
Activity level	A high activity level needs proper neuromuscular control
Defect size	Faster progression of rehabilitation is possible with smaller defects
Defect location	TFJ: slow progression of WB activities PFJ: fast progression of WB activities (with knee in extension)
Duration of symptoms	Longer recovery if symptoms persist longer than 12 months

Table 1: Factors, which should be considered during cartilage repair rehabilitation²⁰. BMI=body mass index, TFJ=tibiofemoral joint, PFJ=patellofemoral joint, WB=weight bearing.

TABLE 2

<i>Phases/aims</i>	<i>Rehabilitation modalities</i>
<i>Phase 1/ protection and activation</i>	<p><i>Cryotherapy, elevation, compression</i></p> <p><i>Continuous passive motion (CPM)</i></p> <p><i>Manual therapy: patella mobilisation and techniques to support rolling and gliding in the TFJ</i></p> <p><i>Soft tissue treatment to support the arthrokinematics in the TFJ</i></p> <p><i>WB exercises (according to WB restrictions)</i></p> <p><i>Gait retraining (according to WB restrictions)</i></p> <p><i>Active and passive ROM exercises in CKC (according to ROM restrictions)</i></p> <p><i>Ergometer (no resistance)</i></p> <p><i>Straight leg raise in varying positions</i></p> <p><i>Isometric activation of the quadriceps and the hamstrings in varying knee flexions angles (CAVE: defect location)</i></p> <p><i>Concentric activation of the quadriceps and hamstrings (CAVE: defect location) in CKC (according to WB restrictions)</i></p> <p><i>Strength training for the hip muscles in partial WB positions (according to WB restrictions)</i></p> <p><i>Neuromuscular training in partial WB positions (according to WB restrictions)</i></p>
<i>Phase 2/loading and functional restoration</i>	<p><i>Cryotherapy (if necessary)</i></p> <p><i>Manual therapy: patella mobilisation and techniques to support rolling and gliding in the TFJ</i></p> <p><i>Shift from concentric to eccentric muscle strength training with consideration of the defect location in CKC and OKC</i></p> <p><i>Increase from static to dynamic loading; implementation of functional movement pattern with low load</i></p> <p><i>Strength training for the hip muscles in full WB positions</i></p> <p><i>Neuromuscular training in full WB positions</i></p> <p><i>Ergometer</i></p>
<i>Phase 3/activity restoration</i>	<p><i>Sport-specific high load strength training (increase of intensity and duration)</i></p> <p><i>Increase of dynamic training with implementation of functional sport-specific agility training</i></p> <p><i>Cardiovascular training</i></p> <p><i>Education and preparation for return to sport</i></p>

Table 2: Examples of rehabilitation modalities in each phase. TFJ=tibiofemoral joint, PFJ=patellofemoral joint, WB=weight bearing, ROM=range of motion, CKC=closed kinetic chain, OKC=open kinetic chain.

FURTHER FACTORS INFLUENCING REHABILITATION

Despite the understandable ambition for a standardised rehabilitation programme, the individuality of each patient has to be considered. Several factors have been identified that should influence the rehabilitation programme. These factors include the nature of the defect (size and location), patient age, body mass index, number of previous injuries, activity level and the demand the patient usually places on their knee^{8,9,30}. Table 1 presents these factors and their possible influence on the rehabilitation process.

REHABILITATION PHASES AND REHABILITATION MODALITIES

The duration of each phase and its rehabilitation modalities might vary between the different cartilage repair techniques due to inherent biological and biochemical differences. Progression through the rehabilitation phases should be based on criteria rather than fixed timelines, however several rehabilitation

modalities and the progression within the rehabilitation programme should be based on the biology of the healing tissue⁹.

Pain and effusion, two optimal indicators for overloading of the joint and the healing tissue, should guide the rehabilitation process and must not be ignored. The phases, including possible rehabilitation modalities, are presented in Table 2.

Phase 1: protection and activation phase

The focus of the first phase of the rehabilitation programme should be on reducing effusion and pain, restoration of ROM, regaining muscular and neuromuscular control, as well as monitoring WB restrictions⁹⁻¹¹.

A primary goal of this first postoperative phase is to reduce pain and effusion. It is well known that pain and swelling can lead to quadriceps inhibition with concomitant negative effects on joint biomechanics, neuromuscular control and increased joint reaction forces. Further, decreased quadriceps activity can result in reduced active ROM, particularly in a loss of active

extension^{31,32}. Additionally, increased intra-articular joint temperature can activate proteolytic enzymes, which have been shown to have a detrimental effect on both healthy and healing cartilage tissue⁵.

The amount of initial WB and the progression of WB activities have to be determined based on the cartilage repair technique and individual factors (age, body mass index, neuromuscular control, associated surgical interventions). Patients have to be instructed to use crutches to reduce WB, this should be regularly assessed using standard bathroom scales^{9,10,33}. The regular assessment is important, as it has been shown that patients do not reliably adhere to the given WB instructions³⁴. Microfracture and ACT have historically required longer periods of WB restrictions with a slower progression compared to osteochondral grafting⁹. Table 3 presents common WB restrictions.

A further main component of this phase is the restoration of joint ROM, as a normal ROM is the first step towards normalisation of joint arthrokinematics, which is essential

TABLE 3

	<i>Tibiofemoral joint</i>	<i>Patellofemoral joint</i>
<i>Week 0-2</i>	ACI, MF: toe-touch WB 20% BW OCT: toe-touch WB 20% BW	ACI, MF, OCT: toe-touch WB 20% BW
<i>Week 2-4</i>	ACI, MF: partial WB 50% BW OCT: partial WB 50%-75% BW	ACI, MF, OCT: increase to full WB with an orthosis locked to extension
<i>Week 4-6</i>	ACI, MF: weekly increase 25% BW OCT: increase to full WB	
<i>Week 6-8</i>	ACI, MF: increase to full WB	

Table 3: Weight-bearing restrictions. ACI=autologous chondrocyte implantation, MF=microfracturing, OCT=osteochondral transplantation, BW=body weight, WB=weight bearing.

to provide physiological loading of articular cartilage tissue. Cyclic dynamic movements in the available ROM in non-WB positions support mechanical stimulation of the cells and increases synovial fluid and nutrition to the healing tissue^{35,36}. Active and passive ROM exercises should be performed in closed kinetic chains (CKC) to prevent shear forces over the repair site^{8,37} as well as pain and effusion.

Muscular activation is a key factor in restoring muscular joint control and normal arthrokinematics. Further, development of muscle strength and endurance is important to distribute forces acting on the knee and to protect the healing site. Muscle strengthening exercises aim at optimising joint loading through improving alignment and the capabilities of the muscles to absorb shock during activity. In particular, quadriceps and hamstring strengthening exercises should be emphasised to restore lower extremity muscle strength and to actively stabilise the knee joint. In addition, the hip muscles (gluteals) play a major role in providing functional joint alignment by preventing lower extremity dynamic valgus^{8,10,38}. In this first phase, isometric and CKC exercises outside of the defect zone are recommended, as they produce no shear forces and damage to the healing tissue can be avoided^{8,9}.

Furthermore, proprioceptive deficits should be addressed in this phase by the implementation of neuromuscular exercises which should be performed within the patient's WB restrictions^{8,9}.

Phase 2: loading and functional restoration phase

The main focus of this second phase is a controlled, but progressive, increase of WB activities. This can be achieved by increasing joint ROM, restoring muscular and neuromuscular control and the beginning of more complex movement patterns, which require proper dynamic joint stability. The ability to generate a sufficient amount of force in a timely fashion is of significance to maintain dynamic stability of the knee and limit excessive joint motion that may affect the static structures such as ligaments and cartilage^{26,39}. Core strength has also been shown to have a significant impact on the loading of the lower extremity⁴⁰⁻⁴². In this phase concentric and eccentric muscle strength training should be emphasised to provide dynamic knee stability. However, this should be done in safe ranges to minimise the danger of jeopardising the healing graft and ensure no increase in symptoms occurs. Neuromuscular exercises can shift from partial WB positions to full WB and the use of additional weight is possible. Both muscle strength and neuromuscular training should be integrated into complex movement pattern exercises and functional tasks. It is still crucial to be cautious that no increase in symptoms occurs during or after the exercises.

Phase 3: activity restoration phase

This phase aims to prepare the patient to return to higher mechanical stress associated with sports activity. A

programme should be developed that allows a continued recovery and meets the biomechanical and physiological demands of the respective sport activities. Further, any remaining muscle strength deficits and additional impairments related to metabolic capacity, sport-specific movement patterns and symptoms should be addressed to provide a safe return to sport⁹.

References

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