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Devices for the prevention and treatment of knee stiffness after total knee arthroplasty

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Persistent pain and dysfunction following total knee arthroplasty require treatment beyond standard rehabilitation. This article discusses devices used to prevent and treat decreased range of motion. If deficits remain after initial standard therapy, multiple devices exist that can be used for nonoperative treatment. Load-control devices apply a constant force, producing variable soft-tissue displacement as tissues stretch. Static progressive stretch devices use the principle of stress relaxation by applying progressively increasing constant displacements. Both types of devices are reported to be effective in treating persistent knee stiffness. The authors feel that future developments will occur in improving treatment protocols for these devices.

Keywords: continuous passive motion • device • displacement-control • load-control • rehabilitation • static progressive stretch • stress relaxation • total knee arthroplasty

Total knee arthroplasty has been shown to have excellent implant survivorship in many reports [1–4]. A majority of patients who undergo these procedures have no postoperative complications related to rehabilitation protocols, and it has been reported that 85% of patients recover excellent knee function regardless of the rehabilitation protocol chosen [5]. However, the remaining 15% of patients may have postoperative difficulty that requires special treatment to regain the level of functionality desired by the patient. Specific rehabilitation technologies and protocols, including the devices discussed herein and manipulation under anesthesia, have been developed in an effort to overcome these problematic patient populations. Although surgical revision is an option, it is preferable to exhaust all nonoperative methods before the risks of a revision procedure are undertaken.

The purpose of this article is to summarize the current knowledge of the various devices used to treat range of motion deficits after total knee arthroplasty, and to offer treatment protocols and usage recommendations. Although factors such as pain management and a return to physical activity are also important considerations in rehabilitation, this article focuses on improvements in range of motion. A literature review was performed using the Medline database to identify relevant articles. The search was performed on March 1, 2010 and included the terms “total knee arthroplasty”, “TKA”, “rehabilitation”, “load-control”, “displacement-control”, “continuous passive motion” and “static progressive stretch”. For each of the device types, the following will be discussed: basic science relevant to the device; treatment protocols and the authors’ recommendations for device implementation; and reported clinical results. The authors will then describe the probable development and advancements that will occur over the next 5 years.

Continuous passive motion

Basic science

Continuous passive motion devices attempt to prevent joint stiffness. There is the potential, following knee arthroplasty procedures, for the patient to remain immobile for various reasons including pain and sedation, or secondary to sedentary behavior prior to receiving a total knee arthroplasty. Prolonged immobilization has numerous adverse effects on the health of synovial joints, including a decrease in the strength of ligament insertion points and an increase in the force required to move the joint through its range of motion [6]. Immobilization also affects oxygen saturation, deep vein thrombosis development and muscle loss, all of which are important clinical implications. Continuous passive motion devices seek to avoid these complications after total knee arthroplasty by mechanically cycling the joint in a slow, passive and controlled

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Figure 1. Custom knee device – load-control brace for treatment of flexion deficit.

manner. The theoretical basis for continuous passive motion devices is to counteract the lack of joint movement by providing a device that passively ranges the joint. In addition to preventing joint stiffness, Salter found that these devices may stimulate tendon and ligament healing in a painless manner that does not create any wound-healing complications [7].

Recommended implementation

In the early postoperative period, the patient's leg is placed on the continuous passive motion machine, with the joint directly over the splint's hinge. The splint's end point is mechanically moved up and down a track in the device, thereby causing the splint to bend at its hinge. The patient's knee follows the hinge and cycles through the programmed range of motion. Care must be taken to ensure that the actual knee flexion achieved corresponds to the setting on the device [8].

Unlike the other devices that will be discussed in this article that are only indicated for problematic joints after standard physical therapy has failed, continuous passive motion devices have been used for any patient immediately after surgery. Evidence suggests that starting with a 50–90° range of motion instead of 0–40° may yield better short-term flexion, but equivalent long-term results [9]. Some studies mention that treatment should begin on the first postoperative day [10,11], while a few studies started on the day of the procedure [9,12–14]. The reported hours per day and total number of days also vary widely in the literature. A meta-analysis reported that treatment time continued for anywhere between 18 h and 2 weeks, with daily durations ranging between 5 and 20 h per day [10].

Results

Numerous studies in the literature (Table 1) have reported on the clinical use and application of continuous passive motion (CPM) devices following total knee arthroplasty. Brosseau *et al.* performed a meta-analysis of the literature through 2003 that included comparative controlled trials of CPM with patients who had undergone total knee arthroplasty for degenerative joint disease [10]. Studies were included if both control and study cohorts received standard physical therapy, and the study group also received continuous passive motion treatment. Using these criteria, 14 studies were selected that had a total of 952 patients. Using CPM led to shorter hospital stays by a difference of approximately 1 day (95% CI: 0.03–1.35 days, based on 382 patients), improved active knee flexion at 2-week follow-up by a mean of 4.3° (95% CI: 2.0–6.6°, based on 286 patients) and lowered the incidence of postoperative manipulation by a relative risk of 0.12 (95% CI: 0.03–0.53, based on three trials). Continuous passive motion demonstrated no significant advantages in other range of motion outcomes. The authors concluded that the benefits of adding CPM to postoperative therapy should be weighed against the increased cost and burden of care, especially considering that the 4° improvement in early active knee flexion may have little clinical significance.

Since 2003, there have been several additional studies that support the conclusion that only small improvements may be seen in range of motion with the use of these devices. Bennett *et al.* prospectively placed 147 patients into three treatment groups who received either no CPM, CPM from 0 to 40° that increased by 10° per day or CPM from 50 to 90° that led to full extension over 3 days [9]. All patients received the same physical therapy program. No difference was seen in length of hospital stay. An advantage in active and passive flexion was found to exist in the 50–90° group at 5 days postoperatively, but the differences were not maintained at longer-term follow-up conducted at 3 months and 1 year. Several other studies have also concluded that CPM offers no benefits in the range of motion as early as 1 week postoperatively, and that the length of hospital stay is unaffected by the use of these devices [11,13,14].

Summary

Continuous passive motion has been the source of much literature debate since its introduction in the 1970s. Most studies demonstrate that long-term range of motion benefits, if any, are small and provide questionable therapeutic value. In addition, some authors even cast doubt on any short-term benefits, especially considering that a range of motion improvement of less than 5° has little clinical relevance. The most comprehensive analysis to date, a meta-analysis performed by Brosseau *et al.*, did demonstrate that the use of continuous passive motion

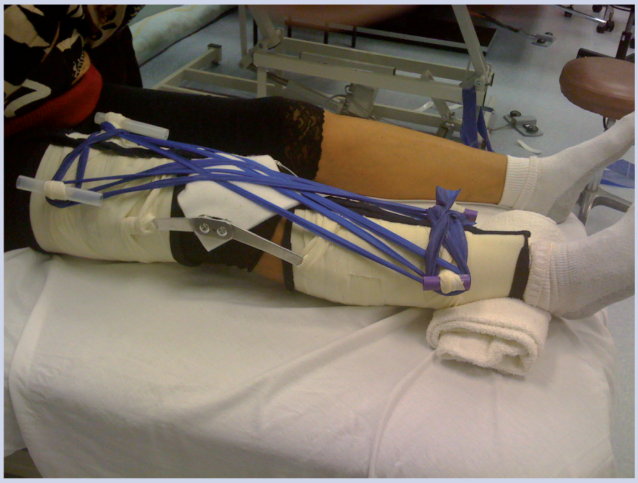

Figure 2. Custom knee device – load-control brace for treatment of flexion contracture.

can shorten hospital stays and reduce the need for postoperative manipulations, although these gains are small. However, fast-track methods (in which patients are discharged within 1–3 days to avoid the risks associated with decreased ambulation that some surgeons feel CPM causes) were not included in this study, as there have been no studies that report on the efficacy of this rehabilitation program. Overall, CPM has the potential to possibly provide a better outcome for patients, and decrease the burden on both surgeons and the healthcare system that comes with manipulations and possible revision total knee arthroplasty [10].

Biomechanics of rehabilitation devices

When an external load is applied, the amount of deformation created in the system can be controlled by either applying a constant force or by deforming the system a specific distance. These two loading parameters are termed 'load-control' and 'displacement-control', respectively. In a load-control system, a constant force is applied to the system, which is allowed to gradually displace over time. By contrast, in a system under displacement-control, a constant amount of deformation is created. Consequently, the system is initially placed under a large amount of stress, which decreases over time as the material relaxes.

Rehabilitation devices used following total knee arthroplasty can be stratified into two groups: those that apply a specific force across the joint (load-control devices) and those that apply a specific deformation across the joint (displacement-control devices). Each group of devices utilizes a different underlying principle based on either load-control or displacement-control. Load-control devices deform soft tissues on the basis of creep deformation, while displacement-control utilizes the concept of stress relaxation. Each of these techniques will be discussed in detail subsequently, and some of the commercially available devices are listed in Table 2.

Load-control devices

Basic science

Load-control devices act on the principle of creep deformation, which is the application of a constant force to gradually stretch soft tissue and increase joint displacement from its original position [15,16]. It can also be referred to as 'low load, progressive stretch', 'low load, prolonged duration stretch' and 'dynamic splinting'. By varying the direction of the applied force, creep deformation can be used to gain either extension or flexion in a stiff knee following failed standard physical therapy modalities [17]. The goal of creep deformation is to cause the connective tissue to undergo plastic deformation. Unlike elastic deformation, in which the tissue returns to its original length after the force is removed, plastic deformation causes tissue remodeling that leads to permanent elongation [18,19].

Table 1. Primary reports investigating continuous passive motion for rehabilitation after total knee arthroplasty.

Study (year)	Treatment type	No. of knees (no. of patients)	Mean age (years)	Methods	Results	Ref.
Brosseau *et al.* (2004)	CPM	NR (952)	NR (all patients ≥18 years)	Meta-analysis of 14 comparative controlled trials in which both control and experimental groups received PT and the experimental group received CPM	Adding CPM to PT decreased hospital stay duration, improved active knee flexion at 2-week follow-up and lowered incidence of postoperative manipulation	[10]
Bennett *et al.* (2005)	CPM	147 (147)	71 (NR)	Patients divided into three groups: no CPM, CPM 0–40° plus 10° per day and CPM from 90° to 50° that led to full extension over 3 days. All patients had same PT	Best active and passive flexion at 5 days postoperative achieved in 50–90° group. No difference in 3-month follow-up, 1-year follow-up or length of hospital stay	[9]
Alkire and Swank (2010)	CPM	65 (65)	66 (all patients ≥18 years)	Computer-assisted TKA patients divided into two groups: PT only and PT with CPM	No difference in length of hospital stay or range of motion at 2-week, 6-week and 3-month follow-up	[14]

CPM: Continuous passive motion; NR: Not reported; PT: Physical therapy; TKA: Total knee arthroplasty.

Table 2. Commercially available rehabilitation devices and their biomechanics.

Commercially available device (manufacturer)	Biomechanics of device
Advanced Dynamic ROM® (Empi, St Paul, MN, USA)	Load-control
Dynasplint® (Dynasplint Systems, Inc., Severna Park, MD, USA)	Load-control
Joint Active Systems (JAS) Orthosis (Joint Active Systems, Inc., Effingham, IL, USA)	Displacement-control Static progressive stretch
Knee Extensionater® (ERMI, Inc., Atlanta, GA, USA)	Load control
Pro-Glide (DeRoyal, Powell, TN, USA)	Load control

Recommended implementation

During rehabilitation following total knee arthroplasty, flexion contracture is the most common indication, followed by flexion deficit [17,20,21]. The length of time the device should be worn is typically based on the recommendations of the therapist in conjunction with those of the device manufacturer. The amount of load to be applied is typically increased as tolerated by the patient. There are few publications concerning creep-based devices, and most of these are case reports dealing with the elbow joint [22–27]. Recommendations for daily usage time vary. Most commercially available devices are worn for 8 h or more per day [28], while some custom devices, such as those shown in Figures 1 & 2, can be worn for shorter durations [20,29]. If both flexion contracture and deficit are being treated, separate sessions are used for each. If these sessions do not yield results, the device can also be worn at night [17]. Treatment can last anywhere from 1 to several months depending on the patient's progress, and is always combined with traditional physical therapy sessions.

Results

Studies published over the past 5 years (summarized in Table 3) have demonstrated that most load-control devices are highly effective in resolving knee flexion contractures and functional deficits that have failed to respond to standard physical therapeutic techniques after total knee arthroplasty.

McGrath *et al.* reported on the use of a load-control device to treat flexion contracture following total knee arthroplasty in 47 patients (29 primary arthroplasties, 18 revisions) who had a mean age of 62 years (range: 47–71 years) [20]. All patients had undergone 4–8 weeks of standard physical therapy and had a mean contracture of 22° (range: 10–40°). When combined with additional physical therapy for a mean of 9 weeks (range: 6–16 weeks), 27 out of 29 patients achieved full extension, which was maintained at a mean follow-up of 24 months (range: 18–36 months). The mean Knee Society knee score improved from 50 to 91 points, and the mean Knee Society functional score improved from 34 to 89 points. Based on these results, the use of a load-control device in addition to standard physical therapy may be beneficial in the treatment of unresolved flexion contracture following total knee arthroplasty.

In a study by Seyler *et al.*, a load-control device was evaluated to resolve both flexion deficits and contractures [17]. The authors reported 79 knee arthroplasties in 78 patients, who all presented with flexion deficit, with or without a flexion contracture. The difficulties resulted from tightness of the rectus femoris muscle, patellar tracking problems and inflammation of the patellar tendon. Load-control treatment and concurrent physical therapy were initiated after the knee stiffness failed to respond to a minimum of 2 months of standard therapy, and in some cases a manipulation under anesthesia. The treatment led to excellent results in 71 knees (90%) and a mean overall improvement in range of motion of 24.7 ± 18.3°. Several other studies have also demonstrated positive results using load-control devices [21,29], including adding them to other methods when treating stiff knees [30].

Evidence is not conclusive regarding the effectiveness of some commercial devices. Finger and Willis presented a case report of a 61-year old man who had a knee flexion contracture of 12° following total knee arthroplasty and standard physical therapy modalities. Full extension was achieved by wearing the device for 6–8 h per night for 8 weeks [31]. However, a report by Steffen and Mollinger investigated its use on 18 nursing home residents with at least 10° of bilateral knee flexion contracture secondary to a variety of causes, which did not include arthroplasty [15]. Using the device for 3 h/day, 5 days/week, for 6 months yielded no advantage over standard passive range of motion and manual stretching therapy [15].

Summary

While some custom-made load-control devices have been shown to be effective in treating both knee flexion contractures and deficits, many commercial devices have the disadvantage that they must be worn for large portions of the day, and can be uncomfortable and obtrusive for the patient. Commercially available alternatives that provide benefits for the wearer while drastically reducing required treatment times will be discussed in the next section.

Static progressive stretch (displacement-control) devices

Historical development of static progressive stretch

The original load-control and displacement-control protocols in the 1970s and 1980s involved long treatment times and often little patient control, with the potential for low compliance. For creep loading, Hepburn *et al.* recommended wearing a load-control knee orthotic for 8–12 h/day to treat knee flexion deficit and contracture [28]. The force settings were adjusted by a physical therapist as treatment progressed. For stress relaxation, Green *et al.* recommended using a custom orthosis molded to the patients' specific anatomy. The load was controlled by turnbuckles located at the joint line, and the orthosis was worn full time to treat elbow contracture [32]. The turnbuckle displacement was increased by the patient as discomfort allowed.

The orthoses presented in these studies had some possible limitations, which have been sustained in many of the modern

Table 3. Primary reports investigating load control for rehabilitation after total knee arthroplasty.

Study (year)	Treatment type	No. of knees (no. of patients)	Mean age in years (range)	Methods	Results	Ref.
McGrath *et al.* (2009)	Load	47 (47)	62 (47–71)	CKD and PT used to treat knee flexion contracture following TKA. Treatment lasted mean 9 weeks (range: 6–16 weeks)	Mean 22° (range: 10–40°) pretreatment contracture improved to full extension in 42 out of 47 patients. Maintained at mean 24-month follow-up (range: 18–36 months)	[20]
Seyler *et al.* (2007)	Load	79 (78)	53 (19–77)	CKD and PT used to treat knee flexion deficit and contracture that did not resolve with standard PT	Treatment led to excellent results in 71 knees and mean overall improvement of 24.7° ± 18.3° in range of motion	[17]
Steffen and Mollinger (1995)	Load	18 (18)	86 (73–95)	Bilateral knee flexion contracture, not from total knee arthroplasty. Bilateral physical therapy treatment supplemented unilaterally with Dynasplint®	Adding Dynasplint to standard physical therapy showed no benefit	[15]

CKD: Customized knee device; PT: Physical therapy; TKA: Total knee arthroplasty.

rehabilitation devices. First, the amount of traction described by Hepburn *et al.* was limited to 5 lbs of load in order to prevent local skin damage. The long daily treatment times required by this loading and the lack of patient control may have led to low compliance. More recent studies investigating stress relaxation and creep loading methods make two marked changes to these previous treatments. First, treatment time is limited to two to three sessions per day that each last 30–45 min [33]. This protocol was first studied in the elbow, with successful results. Second, the patient controls the force applied by the device. Numerous studies have demonstrated that these two changes have been effectively employed by newer devices for stress relaxation [16,17,34].

Historically, serial casting and splinting have been performed to treat severe knee flexion contractures in children with neurological disorders and hemophilia [35,36]. Recently, serial casting has been used with successful results in treating other childhood deformities, specifically clubfoot [37–39]. In this setting, serial bracing can be viewed as a crude form of static progressive stretch, whereby each cast places the joint in a stretched position, allowing gradual soft-tissue relaxation over time. Serial bracing proved effective in these situations, but could actually be considered a form of slow static progressive stretch.

Recommended implementation

The recommended use of static progressive stretch devices, such as the one shown in Figure 3, is in 30-min sessions, which is much more appealing than the 8–12 h that is required per day with many other knee rehabilitation devices. In each session, the leg is secured in the brace at its current motion limit. The patient increases the stretch as tolerated every 5 min. Treatment begins with one session per day for the first 5 days, followed by an increase to a maximum of three sessions per day as tolerated. The sessions are continued until no benefit is seen for at least 1 week [16,34]. One study combined this protocol with intensive physical therapy [17], whereas other studies required clinic visits to measure progress and check for complications [16,34]. Positive results were achieved using both approaches.

Results

Several studies, (summarized in Table 4), have demonstrated static progressive stretch to be effective in reducing both flexion contractures and deficits in the knee following either primary or revision total knee arthroplasty.

Bonutti *et al.* reported on the use of this orthosis to treat 25 patients who had stiff knees following total knee arthroplasty that had not resolved with standard physical therapy [16]. The patients had all previously also undergone unsuccessful manipulation under anesthesia. Patient median age was 53 years (range: 31–79 years). Treatment was conducted for a median of 7 weeks (range: 3–16 weeks) with this device alone (i.e., no concurrent physical therapy). Median increases of 25° (range: 8–82°) in total range of motion, 19° (range: 5–80°) in active flexion and 7° (range: 2–15°) in active extension were maintained at a median follow-up of 22 months (range: 10–24 months).

Seyler *et al.* reported on a series of 29 patients (30 knees) who had soft-tissue contractures following total knee arthroplasty or post-traumatic scenarios [17]. All patients had failed standard physical therapy, began using the device at a mean of 14 weeks after the index surgery or injury, and continued for a mean of 9 weeks (range: 3–33 weeks). All but two patients gained range of motion, and the mean gains were 22.5 ± 16.3° of total arc, 15.1° ± 12.3° of flexion and 7.4 ± 8.1° of extension.

Table 4. Primary reports investigating static progressive stretch (displacement-control) for rehabilitation after total knee arthroplasty.

Study (year)	Treatment type	No. of knees (no. of patients)	Mean age in years (range)	Methods	Results	Ref.
Bonutti *et al.* (2010)	Displacement SPS	25 (25)	53 (31–79)	Orthosis without concurrent PT used to treat post-TKA knee stiffness. Median 7 weeks (range: 3–16 weeks) of self-directed, self-administered home usage	All patients gained total active range of motion (median increase: 25°), active flexion (median increase: 19°) and active extension (median increase: 7°). Maintained at median follow-up of 22 months	[16]
Seyler *et al.* (2007)	Displacement SPS	30 (29)	52 (19–77)	Orthosis used to treat soft tissue contracture following TKA or trauma. Treatment lasted 9.4 ± 7.8 weeks (range: 3–33 weeks)	All but two patients gained range of motion. Mean gains were 22.5 ± 16.3° total arc, 15.1 ± 12.3° flexion, and 7.4 ± 8.1° extension	[17]
Bonutti *et al.* (2008)	Displacement SPS	21 (21)	56 (23–78)	Orthosis used to treat knee stiffness following knee arthroplasty	Mean gain of 25° (range: 4–82°) in total range of motion	[34]

PT: Physical therapy; SPS: Static progressive stretch; TKA: Total knee arthroplasty.

Summary

Based on these studies, static progressive stretch devices appear to effectively treat both flexion contractures and deficits in both the stiff native joint (e.g., post-traumatic), as well as in the stiff knee following total knee arthroplasty. Several studies emphasized that results were achieved without concurrent physical therapy, although no control group existed to determine whether physical therapy would have led to quicker or better results. However, current studies only show the efficacy of this particular device; further comparison studies are needed to determine if there are any advantages or disadvantages when compared with other types of rehabilitation devices or standard rehabilitation techniques alone.

Expert commentary & five-year view

Multiple devices exist to avoid and treat the stiff knee following total knee arthroplasty. Continuous passive motion devices attempt to avoid stiffness before it occurs by continually cycling the patient's leg in a controlled and passive manner immediately following surgery. The literature is divided as to whether continuous passive motion has any long-term range of motion benefits, but some studies suggest it may increase short-term range of motion, shorten hospital stays and decrease the need for postoperative manipulation. In the current environment of insurance pressures and hospital crowding, the authors believe that continuous passive motion devices may provide benefits. However, these benefits have little to do with providing a clinically relevant increase in range of motion following primary total knee arthroplasty.

Load-control devices are only used for patients with flexion contractures and deficits after failure of standard physical therapy. They can be used at home and apply a prolonged, constant force to gradually lengthen the soft tissues, thereby increasing range of motion. The literature has demonstrated that load-control devices, when used in conjunction with physical therapy, are effective in resolving severe flexion contractures and deficits. Custom bracing solutions have been developed using load-control devices that allow for patient-specific loading. This solution is a viable option for patients when a custom fit brace is needed (e.g., severe extra-articular varus/valgus deformity), and allows for a customized load and duration of treatment that may not be offered with other, commercially available load-control devices. However, the practical use of this device necessitates practitioners who are comfortable with the customized application for each patient's knee, with the appropriate location of the hinges to gain extension and/or flexion. Although proponents of this device laud its advantages, it still appears to require extensive experience for correct application, which may be beyond the capabilities of many less specialized centers.

Static progressive stretch and stress relaxation devices have been used when standard therapy did not yield satisfactory results. Although serial casting has been used in the past and is one form of static progressive stretch, the authors do not recommend using this method unless unique circumstances prevent the use of any other form of bracing. Static progressive stretch devices have been shown to yield excellent results, involve the patients in their clinical care by teaching them the method by which to adjust and control the amount of displacement the brace places on the joint, and may not require concurrent physical therapy.

The authors foresee most of the progress over the next 5 years occurring in the protocols and specific applications for the existing devices rather than in the development of any new devices. Continuous passive motion devices have been used for many years. More recently, devices have been developed to specifically treat

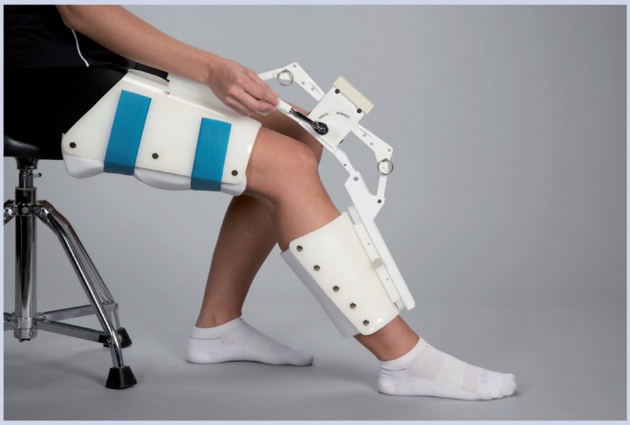

Figure 3. Example of a commercially available displacement-control brace that uses the principle of static progressive stretch.

the stiff knee following total knee arthroplasty. These include both load-control devices and static progressive stretch devices. With the exception of the continuous passive motion device, the optimum implementation protocol has not been thoroughly investigated regarding when to initiate therapy and for what specific applications. Current studies have reported the successful usage of new devices for problematic knees at least 1 month after surgery, and some have shown the added benefit that efficacy has been demonstrated with drastically reduced treatment times. Further research needs to be conducted regarding their specific implementation in order to provide maximum benefit to the patient while further minimizing treatment time.

More randomized controlled trials (RCTs) are needed comparing the results and patient satisfaction between devices and protocols. Future research should focus on designing RCTs in which consecutive patients operated on by the same surgeon are split into equal groups treated with standard physical therapy, CPM, a load-control device or a displacement-control device. The patient groups should be uniform in the underlying reasons for their flexion contractures or deficits. Additional RCTs comparing treatment protocols within each treatment type will help determine the most effective methods for using each device. RCTs comparing promising fast-track rehabilitation methods with any of the above protocols would also be helpful in identifying ways to limit the burden on both patients and the healthcare system. Additionally, because range of motion may improve until 1 year postoperatively, any new studies should strive for longer follow-up than the several weeks or months found in much of the current literature.

The following questions remain to be addressed regarding these rehabilitation devices:

- Would utilizing load- or displacement-control devices in the days following surgery lead to better results than CPM?
- Is it possible to identify patients earlier than 1 month postoperatively who would benefit from the use of one of these devices and ultimately prevent the risks associated with manipulation under anesthesia or further revision surgery?
- Would applying them for a longer duration expedite the excellent results currently reported?

Although preliminary studies continue to show promising results with these devices, these are a few of the many questions that remain unanswered. Further research could possibly lead to improvements in the treatment protocols and will likely constitute the majority of advances in the field.

Financial & competing interests disclosure

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Key issues

- Approximately 15% of total knee arthroplasty patients have persistent joint stiffness and require further treatment.
- Continuous passive motion is the primary rehabilitation device used to prevent stiffness in the days following surgery, but no studies have demonstrated the resultant short-term increase in range of motion to be maintained at follow-up.
- Load-control and static progressive stretch devices can be used to treat knee joint flexion contracture or deficit that does not resolve through standard physical therapy.
- Load-control and static progressive stretch aim for plastic deformation of the soft tissue, which causes lengthening and remodeling.
- Load-control applies a constant force to produce variable displacement in the joint.
- Static progressive stretch is based on stress relaxation and applies a variable force at incrementally increasing displacements.
- Both load-control and static progressive stretch have been demonstrated to be effective treatments for ongoing knee stiffness.
- Historical trends have led to improved load-control and stress relaxation treatment through shorter brace application times enabled by greater device customization and patient control.
- Developments in the next 5 years will probably focus on treatment duration and indications, rather than new inventions or advances in existing devices.

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