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Review Article

The Effectiveness of Exercise Following Proximal Interphalangeal Joint Replacement: A Critical Review of the Evidence

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Abstract

Osteoarthritis of the proximal interphalangeal joint can be caused by trauma, degenerative or rheumatic disease, and can lead to severe pain and functional limitations. Many options are available in the management of proximal interphalangeal joint osteoarthritis, with joint replacement for the PIPJ usually considered after conservative treatment has failed. The purpose of the review is to determine the effectiveness of exercise following proximal interphalangeal joint replacement.

Keywords: Proximal Interphalangeal Joint; Arthroplasty; Rehabilitation

Abbreviations

OA: Osteoarthritis; PIPJ: Proximal Interphalangeal Joint; SEQES: Structured Effectiveness Quality Evaluation Scale

Introduction

Osteoarthritis (OA) of the proximal interphalangeal joint (PIPJ) can be caused by trauma, degenerative or rheumatic disease, and can lead to severe pain and functional limitations [1]. Joint replacement for the PIPJ is usually indicated after conservative treatment has failed [2]. Varying designs of implants have been created and introduced over the years, however many have been withdrawn over time as their shortcomings became apparent in clinical practice [3]. Despite the abundance of literature, few articles evaluate the postoperative rehabilitation in PIPJ replacements, in particular the effectiveness of exercise post-operatively [3,4]. The purpose of the following review is to determine if exercise is effective following PIPJ replacement.

Materials and Methods

Search Strategy

The following databases were electronically searched to identify relevant articles: Allied and Complimentary Medicine Database (AMED), Cumulative Index of Nursing and Allied Health Literature (CINAHL), MEDLINE, PubMed Central, and Science Direct. Titles and abstracts were screened, duplicates were removed, then the remaining full texts were assessed against the inclusion and exclusion criteria (Table 1). Due to the high number of studies available, studies using only the Ascension Pyrocarbon implant (Ascension Orthopedics, Inc., Austin, Texas) were included, as this is the implant of choice by the hand surgeons in our clinic. Fifteen studies fit the criteria. Critical appraisal and quality of the studies were assessed using the Structured Effectiveness Quality Evaluation Scale (SEQES; 5). This was chosen as it provides a tool for evaluating intervention studies and is suitable for use with a variety of study designs. It is a 24-item standardised worksheet where each item can be scored either 2 (high quality), 1 (fair quality) or 0 (poor quality) providing a total possible score of 48.

Discussion

Critical review of the effectiveness of exercise following proximal interphalangeal joint replacement

The overall quality for the articles ranged from 14-25 on the SEQES evaluation. The most striking limitations identified by the SEQES evaluation were in relation to methodological quality, particularly inadequate blinding of subjects, lack of an independent evaluation of outcome measures, power to identify treatment effects and randomisation strategies. Only one study [6] adopted a randomised comparative approach to their investigation enabling this study to be of the highest quality on the SEQES evaluation (25/48). An advantage of randomly allocating participants is that

Inclusion	Exclusion
• PIPJ replacements • Male/female above 18 years of age • Described a therapeutic intervention with follow-up postoperatively • Included a description of the postoperative regimen, including immobilization period, immobilization method, or description of exercises/physical therapy treatment; • Ascension pyrocarbon implant • Included a comparison of results over time (e.g. pre-operative and post-operative) • Included range of motion, pain intensity and/or limitations in ADL and/or grip and pinch strength as outcome measures • Published within last 15 years	• Single case reports • Language other than English • Documented only surgical technique/ review papers • No rehabilitation or exercise programme reported • Reported only radiographic outcomes • No pre-operative outcomes taken

Table 1: Inclusion/Exclusion Criteria.

selection bias and the effects of confounding variables are reduced, thus increasing the validity of the results and the confidence therapists can have in the study [7,8].

A limitation across all included studies was their poor reporting quality. Insufficient detail was provided on the exercise programmes, primarily with regards to the intensity and frequency of the exercises (Table 2). Studies that did provide some guidelines were considerably vague, for example "unrestricted grip activities" (9) or "light, controlled activities" [10]. As there is a risk of further damaging a joint by exercising at an inappropriate intensity [11], studies should ensure sufficient detail is provided to enable the reader to fully understand the specific treatment that was implemented to replicate in practice. The lack of transparency in reporting affects the ability to adequately assess the validity of the results [8].

A crucial aspect in any clinical study is the calculation of an adequate sample size [12,13]. No study reported their power calculations thus it is difficult to identify if the studies had sufficient

Authors	Exercise Regime
Bravo., *et al*. (2007) [46]	**4–7 days:** Begin active PIP joint flexion 0° to 30°, assisted extension in dynamic splint **weeks:** If no extension lag, increase PIP joint flexion to 45° **weeks:** Discontinue dynamic splint if extension has been maintained; buddy tape to adjacent digit; allow flexion to 60° **6 weeks:** Increase PIP joint flexion with goal to achieve 0°–75° of motion **3 months**: Activities as tolerated, splinting as needed
Chung., *et al*. (2009) [20]	**1 week post op:** initiate flexion and extension exercises in a dynamic splint. Continue these for 8 weeks.
Daecke., *et al*. (2012) [6]	**0-2weeks: A**ctive ROM exercise without any passive strain, 4 times, 20 minutes a day. **weeks:** Nocturnal splinting, and physiotherapy with a gradually increasing proportion of passive exercises prescribed. **weeks:** The joint was mobilized completely.
Desai., *et al*. (2014) [47]	**within 72 hours after surgery:** Initiate active ROM from 0–60°. **3 weeks:** Unrestricted active flexion was permitted with passive flexion if required. **6 weeks:** If patients had persistent stiffness (flexion < 90°), a manipulation of the joint under local anesthesia was performed in the outpatient clinic
Heers., *et al*. (2012) [9]	**2 days post op**: Initiate active flexion to 30° **2 weeks: P**ermitted active flexion to 50° **6 weeks:** Permitted active flexion to 80° **3 months post op:** Unrestricted grip activities (if radiographs were unremarkable)
Herren., *et al*. (2006) [48]	**Immediately post op:** Active mobilization out of splint, several times a day and worn for a total of 6 weeks **6 weeks:** Full functional use was encouraged after 6 weeks.
Hutt., *et al*. (2012) [49]	**0-2 weeks:** Full immobilisation in extension **2weeks+:** Initiated active gradual flexion, supplemented by dynamic splinting, if required, until a plateau of maximal flexion was achieved.

Mashhadi., *et al*. (2012) [50]	**1 week post op:** With wrist flexed — isolated PIPJ and DIPJ flexion in splints ensuring full active extension to 30° **2 weeks:** Continue exercises within splint up to 40° of flexion at PIPJ **3 weeks:** Continue exercise within splint up to 50° of flexion at PIPJ **4 weeks:** Start full active tendon gliding exercises. No passive finger flexion. **8 weeks:** Composite passive flexion permitted if required **12 weeks:** Return to full function, including contact sports
McGuire., *et al*. (2011) [25]	**5 days post op:** The finger restraining straps were removed every 2 hours for active flexion exercises to a maximum of 45° of flexion at PIPJ **2weeks**: Continue exercise within splint up to 60° of flexion at PIPJ **3weeks:** Unrestricted active flexion permitted at the PIPJ **4weeks:** Passive flexion if required
Nunley et al (2006) [17]	**1 week post op:** Limited active arc-of-motion exercises starting at 0° to 30° of motion. **6 weeks:** Goal of at least 0° to 75° of active PIP joint ROM by 6 weeks; if accomplished, gentle stretching was initiated and light functional activities out of the splints were allowed.
Reissner et al (2014) [21]	"Irrespective of the surgical approach, post-operative rehabilitation included immediate active mobilization. The splint, which was worn as protection for a total of 6 weeks, was removed several times a day."
Sweets and Stern (2011) [16]	**1 week: A**ctive motion of the PIPJ was initiated 7 days post op. AROM of unaffected joints was encouraged. **Week 3:** Active flexion of the PIPJ was encouraged and a dynamic proximal interphalangeal joint extension splint was applied. Active range of motion of the metacarpophalangeal and distal interphalangeal joints was continued. **6 weeks:** Full tendon gliding and composite fist exercises were initiated passive range of motion was added at six to eight weeks, **8-10 weeks:** Light strengthening initiated **10-12 weeks: T**herapy was usually complete and the patient was discharged to a home program with an extension splint worn at night for three to six months.
Tagil et al., (2014) [14]	**4–7 days post-operatively:** Active flexion exercises, x5 daily, with a dynamic splint that had an extension device and extension block that limited the last 15–20° of extension over the PIP joint. **2 weeks:** Active flexion exercises within splint to be performed hourly. The dynamic splint was used during the day until the sixth week after operation. **6 weeks:** Unrestricted ROM. Static splint during the night for another 6 weeks.
Tuttle and Stern (2006) [19]	**1 week post op:** Radiographs were taken to confirm reduction and component positioning. If the joints were reduced, supervised active ROM was initiated by hand therapists during the day with night time static extension splinting for 6 weeks.
Wijk et al (2010) [10]	**4 to 7 days postoperatively** Initiate AROM within a dynamic splint during daytime **5th and 6th weeks**, The splint is only used occasionally and light, controlled activities are permitted without the splint.

Table 2: Exercise guidelines in included studies.

power to identify treatment effects. One study included 89 joints; (65 participants, 14), but the average number of digits that underwent arthroplasty across the studies was 30 which may have increased the likelihood of type II errors. This can lead to a high risk of failing to demonstrate a real difference [7,15]. Inadequate sample sizes and inadequate sample techniques can lead to sample bias and poor external validity, which in turn can prevent authors from drawing a reliable conclusion from the data [7]. This is critical to note as important clinical decisions regarding the future of the use of this implant were made based on the results of these studies. Sweets and Stern (2011) [16] concluded to terminate the use this implant in their practice and Nunley., *et al*. [17] terminated their study early due to poor early outcomes and complications. By failing to report a power analysis, no assumptions can be made about the adequacy of the sample size for minimising chance findings [18].

The participants across the studies were similar in terms of size, age and diagnosis. The majority of patients were diagnosed with OA, though some studies selected participants based on the severity of their OA. Tuttle and Stern (2006) [19] selected only patients with "severe" OA, but due to the small sample size (n = 6), they were unable to ascertain whether post-operative therapy, sample selection, or the surgical approach had influenced the results. Participants with all grades of severity of OA were included in most other studies, thus, the patient population that the results may apply to were maximised.

The studies varied in their length of follow-up after surgery. Follow-up refers to the points in time when the outcome measures were evaluated. The shortest was 12 months [20] and the longest 116.5 months [21]. Longer follow-up did not equate to better outcomes in terms of range of motion, pain relief or grip strength. Reissner., *et al.* (2014) [21] reported a significant improvement in grip strength at the two-year follow-up review, however on the final follow-up review at 116.4 months, they found a decrease in grip strength for their participants. No cause was identified for this reduction. The authors also reported a significant reduction in ROM at this point which could have contributed to the overall reduction in grip strength, but a progression of OA in other joints could have contributed to the reduction too. Not all studies specified who had carried out the outcome measures, (e.g. the surgeon or hand therapist) thus it is difficult to compare these. No information was provided on the duration, frequency or length of follow up of hand therapy sessions specifically. Reporting the length of follow up for therapy may enable therapists to be better informed in the planning of rehabilitation with their clients in practice.

The lack of clear description of the rationale and content of the exercise intervention impedes an understanding of the effect of exercise post PIPJ replacement. Bandholm and Kehlet (2012) [22] urge thorough reporting of an exercise intervention before it can be implemented into clinical practice. They provide several suggestions for describing them, for example, contraction types, time under tension, range of motion, number of repetitions and number of minutes. All these components could enable a better understanding of the type of exercise and greater implementation of the exercise in practice. Only two studies, Wijk., *et al.* (2010) [10] and Tagil., *et al.* (2014), [14] provided some justification for their choice of exercise, which is a considerable strength of these studies as it provides readers with the opportunity to understand why a particular type of exercise was used. Early in the use if the Ascension implant, the authors of these studies found that some digits had progressed into hyperextension at the PIPJ, resulting in difficulty initiating flexion and these patients required further surgery to address this. The exercise protocol was then changed, providing an extension block splint and emphasising that the goal of treatment was no longer full extension. The frequency of exercises was reduced to five times a day in the first week post-operatively, then intensifying to hourly in the subsequent weeks. They fail to provide a reason for this. The rapists would be better informed in the planning of their own exercise protocol in practice if the authors were to provide a better justification for the adjustment in the frequency of their exercise. The remaining studies failed to provide sufficient detail on frequency or intensity of exercises to be performed.

As a consequence of the nature of exercise therapy, neither care providers nor patients can be blinded to exercise therapy, resulting in a potential source of bias. A consistent low score on the SEQES across all studies was that an independent evaluation of outcome measures was not carried out. Not one study explicitly reported a blinded approach to outcome measurement. Issues with blinding or independent assessors could have given rise to type I errors [7], or a false-positive, as assessors who are aware of the purpose of the study can influence the results, positively or negatively, leading to the possibility of publication bias [18]. Bias and error can influence the results of a study thus threatening the reliability and validity of data, thus, it is important that researchers strive to constantly take steps to eliminate or minimise these from the beginning in research design [7]. Blinding of outcome measurement is crucial to ensure unbiased ascertainment of outcomes [23].

A key strength of the studies was that the outcome measures used are readily available in most hand clinics. They measured components of body structures and functions as identified by the International Classification of Functioning. These included the Visual Analogue Scale (VAS), range of motion, and grip strength. Very little information was provided on the standardised measurement, the psychometric properties, or what was considered clinically important change in any of the studies. It is difficult therefore to ascertain the reliability and validity of the data collected and is not biased by extraneous factors [24].

Outcomes in ROM can be found in Table 3 and were varied when the results of all studies are considered. McGuire., *et al.* (2011) [25] reported the greatest improvement in post-operative ROM (36°) and report this as extremely statistically significant ($p < 0.0001$). This study also had one of the largest cohorts ($n = 57$). Reporting confidence intervals or a power calculation could have increased the credibility of the results [26]. A study should be designed in a way that potential sources of bias are reduced, however as this study was retrospective in nature, and no clear measures were found limiting confounding variables, it is difficult to exclude a bias from the results [24].

Pain is one of the most limiting factors in OA, and often one of the goals of surgery for the arthritic hand is to manage the pain experienced by the individual [27]. This is reflected in that thirteen of the fifteen studies included some form of assessment of pain (excluding 20 and 25). Most studies demonstrated a considerable reduction in pain at various time points post-operatively. No infor-

Authors	Number of digits	Mean follow up period (months)	Mean preop AOM*	Mean post op AOM	Gained AOM
Bravo., *et al*. (2007) [46]	50	37	40	47	7
Chung., *et al*. (2009) [20]	21	12	40	38	-2**
Daecke., *et al*. (2012) [6]	18	35	56	61	5
Desai., *et al*. (2014) [47]	20	42	40	70	30
Heeren., *et al*. (2006) [48]	17	19	34	42	8
Heers., *et al*. (2012) [9]	13	99.6	46	58	12
Hutt., *et al*. (2012) [49]	18	74.4	40	45	5
Mcguire., *et al*. (2011) [25]	57	27	30	66	36
Mashhadi., *et al*. (2012) [50]	24	48	36	46	10
Nunley., *et al*. (2006) [17]	7	17	32	30	-2**
Reissner., *et al*. (2014) [21]	15	116.5	36	29	-7**
Sweets and Stern (2011) [16]	31	55	57	31	-26
Tagil., *et al*. (2014) [14]	89	60	53	54	1
Tuttle and Stern (2006) [19]	16	13.4	53	53	0
Wijk., *et al*. (2010) [10]	53	24	56	52	-4
Average	30	45.3			

*AOM: Arc of motion at PIPJ

** - indicates degrees of motion lost

Table 3: Range of motion for the PIPJ.

mation was provided on the timing of pain assessment in relation to the exercise programme. A shortcoming of the studies was that they did not control for or report any cointerventions such as medications or joint protection education, both of which could enable better pain management and contributed to the reduction in pain scores post-operatively. This could have led to confounding, which in turn could have affected the results of the studies [7].

Most studies that assessed function reported a slight improvement post-operatively, though these findings were not significant. As the majority of patients had OA, it could be argued that improvement in one particular joint post-operatively may not reflect a significant improvement in function as the disease could impair adjacent fingers [19,25]. Chung., *et al.* (2009) [20] found large effect size (> 0.8) in all domains of the Michigan Hand Outcomes Questionnaire. This is considerable strength of this study as effect size and confidence intervals are the most relevant statistic for establishing the efficacy of an intervention and in conducting evidence-based practice [26,28].

There remains a paucity of high-quality studies analyzing the effectiveness of exercise specifically following PIPJ replacement with insufficient information on type, intensity and frequency of exercise. Further well-designed trials are required to determine the value of exercise following PIPJ replacement. Studies presented here provided mixed results and it would be difficult to conclude at this time that exercise is ineffective, especially since some of the results indicate promising potential benefit of exercise following PIPJ replacement.

Benefits and limitations of exercise following PIPJ replacement

A benefit of active exercise at a cellular level is that it facilitates increased blood flow, produces an elongation and reorganisation of the collagen fibres, and thus prevents adhesions at the surgical site [29,30]. The term mechanotransduction describes this process by which cells respond to mechanical loading, and it is through this process that therapists can promote structural change within the tissue at a biological level [31]. During the fibroplasia stage of healing, fibroblasts begin synthesising collagen, and when viewed under a microscope the collagen fibres are oriented in a random manner as opposed to liner in normal collagen tissue [32] and active exercise facilitates the reorganisation of these collagen fibres [29,30]. Immediate active movement initiated post-operatively can aid in oedema management and prevent tendon adhesions from occurring, both of which can impact recovery and function [33].

Inappropriate or aggressive exercise, however, can lead to an increased inflammatory response, which can be detrimental to wound healing as the strength of the wound is still weak [32]. Moderate intensity exercise increases anti-inflammatory and decreases pro-inflammatory cytokines and molecules [34] and although inflammation is a critical part of the physiological process of healing [35], excessive mechanical loading in the early phase of healing can potentially prolong the synthesis of collagen, leading to hypertrophic scarring [36]. Overly aggressive exercise can also increase tension on the wound site, which can delay wound healing, increase the possibility of hypertrophic scar, increase the likelihood of necrosis and decrease the tensile strength of the wound [29,37]. In the literature presented above, the majority of articles were not clear in their intensity or frequency of the prescribed exercises. A limitation of exercise is that it is difficult to monitor the intensity in which patients should perform the exercises, and with the multiple complications reported in the literature therapists should exercise caution following surgery and provide an appropriate amount of movement to the injured area [38].

A considerable benefit of exercise is that it can promote confidence and sense of independence [38]. Frequent practice of techniques during therapy sessions increases confidence and can also increase compliance with the home exercise programme [39]. Not only does exercise affect muscle fibres at a biological level, it can promote a sense of independence and capability [38]. This sense of confidence however can also provide an individual with a false sense of security in which the individual carries out excessive or activity that the joint may not be prepared for, which in the early stages of recovery, could be harmful to the joint and healing.

Exercise can become prescriptive with a focus on protocols rather than on the patient themselves [38]. The studies evaluated above, however, did not typically mention the use of an occupation-based approach to exercise following PIPJ replacement. By keeping exercises versatile and simple to carry out, patients can perform them at a time and place that was convenient for them, which can lead to increased compliance with their home exercise programme.

Biopsychosocial factors in exercise

The biopsychosocial approach to client care and the 'International Classification of functioning, disability and health framework' encourage the therapist to consider the dynamic relationship between a client's health condition, environment and their personal factors [40]. It provides a framework for the therapist to influence recovery by implementing interventions that address a much broader range of factors that impact client outcomes as compared to the medical model [41,42].

Huber and Wells (2006) [38] encourage therapists to not only consider the nature of the condition and their response to injury, but also the persons support system, roles and responsibilities. Family members were encouraged to join therapy sessions to not only learn and assist in exercise, but also understand of the purpose of the exercises. Support at home can enable individuals to have confidence to carry out their exercises, particularly in the beginning of the recovery process. In ensuring the exercises were easily incorporated into a routine and busy schedule by adjusting the frequency and types of exercise, patients can continue with their exercises within their available resources.

Education plays an important role in the rehabilitation process [41]. The biopsychosocial approach includes a consideration of factors including the role of sleep and nutrition in healing [41] and although they may be addressed as biological factors [42] they also correlate with psychological factors including mood and ultimately poorer rehabilitative outcomes [43] Education included the effect of sleep and nutrition on healing, and also strategies around following a consistent sleep schedule, limiting electronic devices and the consumption of alcohol before bedtime [44].

Exercises can be adapted according to stage of healing and state of the tissues or joints and used to impact the physical structures within the finger at a biological level. Active range of motion exercises are typically used in the fibroplastic phase and are used to maintain existing joint and soft tissue mobility, reduce oedema, reduce risk of joint contractures and tissue adhesions [45]. Exercise also stimulates blood flow bringing out an increase in anti-inflammatory substances and downregulating inflammatory substances, delivering more oxygen, which is crucial in the healing process [29,30]. The exercise programmes found in the literature progress their exercises in terms of range almost weekly, however they do not report on progressing exercise in response to changes in tissue, or complications such as scar adhesion. Some articles did advise passive flexion after 3 weeks (e.g. Daecke *et al.*, 2012), though they do not specify whether this was to include a stretch. Slow, low-intensity stretches were used to impact the physical structures within the finger, separating adjacent collagen fibre attachments to hypothetically allow for long-lasting or plastic elongation. Exercises can be adapted throughout the stages of healing to affect the finger at a biological level.

Personality, personal factors and motivation are considered as components of the psychological factors of the biopsychosocial model [41]. A benefit of exercise in this stage is its versatility and that it can be adapted to needs or interests. Active client participation can be fostered by enabling patients to identify and prioritise their perceived deficits, goals, and her preferred approaches to intervention. The adoption of an occupational focus can be beneficial, ensuring exercises are suited to their interests and task oriented. For example, grasping objects large in size and diameter, such as an empty bottle, and progressing to grasping objects that were smaller in diameter, such as a marker. Tailoring the exercises with an occupational focus, and using objects they have access to daily, can lead to an increased compliance to exercise, self-efficacy and motivation [41,43-50].

Conclusions

Multiple studies have been published on the use of pyrocarbon implants for PIPJ replacement. A limitation of this review is that the search strategy was not exhaustive possibly missed out on some potentially relevant articles. Though the studies evaluated above provide information on post-operative rehabilitation protocols, few give sufficient detail on exercise, including the frequency, type and intensity. Many of the articles were found to be of low-quality with bias present throughout, limiting the validity and reliability of the results. Further research is required, with sufficient detail on the intensity, frequency and type of exercise, to determine if exercise is effective following PIPJ replacement.

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Conflict of Interest

None.

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