The aim of this systematic review is to understand which surgical procedure provides better results in terms of pain relief and function in the treatment of chronic exertional compartment syndrome (CECS) of the forearm.

We searched Medline (PubMed), Web of Science, Embase and Scopus databases on 8 July 2020. Twelve studies were included in this review.

We assessed the quality of the studies using the Coleman Methodological Score.

Data on demographic features, operative readings, diagnostic methods, follow-up periods, type and rates of complications, survivorship of the procedure, return to sport activity, and outcome measures were recorded.

In conclusion, compared to the other techniques, endoscopic fasciotomy delivers similar success rates and lower incidence of complications.

Keywords: chronic; compartment; exertional; forearm

Cite this article: EORT Open Rev 2021;6:101–106. DOI: 10.1302/2058-5241.6.200107

Introduction

The aetiology of chronic exertional compartment syndrome (CECS) remains debated. Today, the most accredited theory reports that a non-compliant fascia stiffens the compartment that fails to adapt to increased blood flow and muscle volume during exercise. CECS of the lower limb is well reported; whereas CECS of the forearm is a rare condition in the general population, but can be observed in motorcycling racers, climbers, and rowers.

Clinically, the symptomatology is characterized by forearm pain, stiffness, decreased muscle strength, and paraesthesias. Symptoms disappear when the exercise is stopped. CECS has been described to occur bilaterally in 70% to 100% of patients. Conservative treatment is effective but mainly consists of suspending the trigger activity, which is generally rejected by patients.

Four compartments are usually described in the forearm: superficial volar compartment, deep volar compartment, lateral compartment, and dorsal compartment. Open fasciotomy has been considered the gold standard for its ability to release all the compartments. However, the invasive nature of open procedures affects high-level athletes with lengthy periods away from competition. It is for this reason that mini-open techniques were proposed to allow for faster recovery and reduce secondary scar formation. More recently, endoscopic techniques have been proposed by different authors, which guarantee continuous visual control during the surgical procedure.

This is a comprehensive review of studies published on the management of patients with CECS, which aims to investigate which surgical techniques provide better outcomes, with fewer serious or major side effects and faster return to sport.

Methods

A systematic review of the literature was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The combination of keywords “compartment chronic forearm” OR “exertional compartment forearm” OR “exertional forearm” were used for the search, with no limits for year of publication. Medline (PubMed), Web of Science, Embase and Scopus were accessed on 8 July 2020, and articles in English were identified. All prospective or retrospective clinical studies reporting data of patients affected by chronic exertional compartment syndrome were considered. Only
Biomechanical studies, studies on animals or cadavers, technical notes, letters to the editor, reviews, and instructional courses were excluded. Two authors independently assessed the abstract of each publication. When the study could not be included or excluded based on the abstract, a full-text version of the article was downloaded. If the full text was not available, the article was excluded from the study. In addition, the reference list of each selected article was searched manually to identify any additional studies missed during the electronic search.

The two investigators assessed each study according to the Coleman Methodological Score (CMS); a score ranging from 0 to 100. Seven Both investigators performed the CMS assessment twice, with an interval of 10 days, and they discussed the scores until consensus was reached when more than a two-point difference was present. Data on demographic features, surgical procedures, diagnostic methods, follow-up periods, type and rates of complications, return to sport, recurrence, and outcome measures were recorded.

**Results**

A total of 299 studies were identified after the first search. Thereafter, 87 studies were selected on the basis of the abstract, 75 were excluded after the full text had been read, and 12 publications relevant to the topic were included (Fig. 1). All included studies were published between 2005 and 2020. The total number of patients was 336: 98.5% (331) were male and 1.5% (5) female. The total number of forearms treated was 605, with 80% of patients (269/336) receiving a bilateral fasciotomy (Table 1). The mean age of the patients at the time of treatment was 25.1 years (range 16.8–34.0 years), one study did not report data on age, and the mean follow-up time was 56.7 months (range 3.0–97.2 months).

**Quality assessment**

All the Coleman scores are given in Table 1. A score of > 85 is considered excellent, 70 to 84 is good, 50–69 is moderate, and < 50 is poor. The mean CMS was 55.3 (range 39.0–74.0).
Diagnosis

The diagnosis was clinical in all the studies. Intra-compartment pressure was measured in ten studies. Magnetic resonance imaging (MRI) was performed in three studies.

Surgical techniques

Five studies involved an open fasciotomy. Three studies involved a mini-open fasciotomy. An endoscopic fasciotomy was performed in three studies. One study compared two techniques: open vs. mini-open. The number of compartments released in each study is indicated in Table 1.

Outcomes

Patient satisfaction was reported in five studies. Pain relief (visual analogue scale [VAS] score) was reported in six studies. Functional scale (the Disabilities of the Arm, Shoulder and Hand (DASH) and QuickDASH) were reported in four studies. Outcomes are reported in Table 2.

Return to sports

Return to sport is reported in Table 3. The average time before return to sport for open, mini-open and endoscopic fasciotomies was 5.3 weeks, 3.8 weeks and 4.4 weeks, respectively. The overall average time before return to sport was 5 weeks (range 2.7–9.0 weeks).

Complications

The complications are reported in Table 3. Three studies did not report any complications.

Recurrence

Seven revision procedures were reported. They are displayed in Table 3.

Discussion

The CMS allowed for the detection of several areas with deficiencies. All the studies, except one, were case studies. Ideally, study design would follow a randomized control trial design, but this is difficult to achieve in clinical practice.

Motorcycle racers (93.7%, 315/336) represented the most affected population in this systematic review. This could be attributed to the way these athletes grasp the bike handlebars with continuous bimanual grip.

Clinical assessment remains the gold standard for diagnosis of CECS. Intra-compartment pressure measurement is widely used; however, there are differences regarding the timing of measurements: six studies measured intra-compartment pressure during exercise or immediately after cessation, while in six studies the pressure was measured from 1 to 5 minutes after exercise. It is interesting that none of the studies measured the intra-compartment pressure after the surgical procedure.
MRI is a valid diagnostic alternative, with the advantage of being less invasive but at the same time more expensive.\(^{18}\) We believe that MRI can be useful as an alternative for measuring hydrostatic pressure, but it would be redundant to use both methods.

We categorized the surgical fasciotomy techniques into three groups: open, mini-open, and endoscopic. Among these categories there was no uniformity, as indicated in Table 1; in fact the number of compartments released can be variable independently from the technique. Furthermore, there are four studies\(^{9-11,16}\) where the number of compartments released changes depending on the surgeon’s clinical judgment.

The reported outcomes revealed that fasciotomy is an effective technique in terms of patient satisfaction, pain relief (VAS) and functional scores (DASH and QuickDASH).

### Table 2. Subjective outcomes

| Study               | Satisfaction             | Pre-op VAS | Post-op VAS | Pre-op DASH/QuickDASH | Post-op DASH/QuickDASH |
|---------------------|--------------------------|------------|-------------|-----------------------|------------------------|
| Zandi 2005\(^{10}\)  | N/A                      | N/A        | N/A         | N/A                   | N/A                    |
| Crouzet 2009\(^{9,7}\) | 100% satisfied          | N/A        | N/A         | N/A                   | N/A                    |
| Brown 2011          | 11/12 very satisfied     | N/A        | N/A         | N/A                   | N/A                    |
| Winkes 2012\(^{12}\) | 83% very satisfied       | 5.3        | 0.7         | N/A                   | N/A                    |
| Garcia-Mata 2013\(^9\) | N/A                    | N/A        | N/A         | N/A                   | N/A                    |
| Harrison 2013\(^9\)  | N/A                      | N/A        | N/A         | N/A                   | N/A                    |
| Barrera-Ochoa 2016  | 32/34 patients very satisfied | 7.8   | 1.5         | 84                    | 15                     |
| vs. mini-open       | 2 fairly satisfied (1 MOF, 1 OF) | 7.8   | 1.7         | 86                    | 12                     |
| Jans 2015           | N/A                      | 7.4        | 1.7         | N/A                   | N/A                    |
| Pegoli 2016         | N/A                      | 4.5        | 0.7         | 21.7                  | 5.4                    |
| Gondolini 2019      | N/A                      | 6.8        | 2.4         | 84                    | 12                     |
| Schiavi 2020        | N/A                      | 6.9        | 2.6         | 79                    | 17                     |
| Ruyer 2020\(^{16}\) | 78% very satisfied       | N/A        | 23          | 1                    |                         |

**Note.** Visual Analogue Scale (VAS); the Disabilities of the Arm, Shoulder and Hand (DASH); mini-open fasciotomy (MOF); open fasciotomy (OF).

### Table 3. Number of procedures, complications, revisions and return to sport/work

| Study               | Surgical technique | N of patients | Complications                           | Revision procedure | Return to sport\/work (weeks) average |
|---------------------|--------------------|---------------|-----------------------------------------|--------------------|--------------------------------------|
| Zandi 2005\(^{10}\)  | Open               | 6             | 1 haematoma                             | None               | 6                                    |
| Crouzet 2009\(^{9,7}\) | Mini-open        | 8             | 1 scar problem                          | None               | 6                                    |
| Brown 2011          | Open               | 12            | 1 haematoma                             | 1                  | 9                                    |
| Winkes 2012\(^{12}\) | Open               | 24            | 2 scar problems                         | None               | 4                                    |
| Garcia-Mata 2013\(^9\) | Open            | 5             | 1 paraesthesia                           | None               | 6                                    |
| Harrison 2013\(^9\)  | Open               | 6             | 1 paraesthesia                           | None               | 4                                    |
| Barrera-Ochoa 2016  | Open vs. mini-open| 34            | 2 haematomas 1 cutaneous problem 1 superficial infection | Open 3           | Mini-open 3                          |
|                     |                    |               |                                         |                    | 6                                    |
| Jans 2015           | Endoscopic         | 154           | 5 haematomas none 1 skin problem 2 superficial infections | None               | 6                                    |
| Pegoli 2016         | Endoscopic         | 3             | 3 scar problem none                     | None               | 3                                    |
| Gondolini 2019      | Mini-open          | 54            | 2 haematomas none 3 hypoesthesia        | 2                  | 3                                    |
| Schiavi 2020        | Mini-open          | 9             | 3 scar problem none                     | None               | 3                                    |
| Ruyer 2020\(^{16}\) | Endoscopic         | 21            | 2 haematomas                            | 2                  | 4                                    |
Studies\(^5,13,16\) which involved limited fasciotomy of the superficial volar compartment reported outcomes in terms of satisfaction and remission of symptoms that were at least equal to studies which involved open fasciotomy. For this reason we agree with the hypothesis of Chan et al.,\(^4\) that forearm compartments are interconnected and there is a balance of the pressure level, especially through the interosseous membrane.

Haematoma was the most common complication (4.5%, 15/336), with no differences in terms of percentage among the techniques. We can assume that the theoretical advantage of better bleeding control afforded by the open technique compared to the endoscopic does not find credence. When we compared time to return to sport, we noticed that mini-open and endoscopic techniques required a shorter recovery time compared to the open technique. This result was expected because the two techniques are less invasive and require less surgical exposure. Some authors\(^16,19\) report late onset of lateral epicondyloitis; they hypothesize that this is due to the remission of CECS which allows the athletes to train at higher intensities.

Our study has several limitations. Firstly, the number of studies included in our review is limited; furthermore, some studies have a small group of patients and there is just one study which compared mini fasciotomy to open fasciotomy. Secondly, fasciotomy was categorized into three groups (open, mini-open, and endoscopic) but there were differences among the studies in terms of compartments released, and these were not categorized. Thirdly, the different methods of assessing and presenting results did not allow for statistical analysis.

**Conclusions**

In comparison to the other techniques, endoscopic fasciotomy delivers similar success rates and lower incidence of complications. Furthermore, because this procedure is minimally invasive, it has the advantage of a faster return to sport and less impact on cosmetic appearance. Further comparative studies are needed to support these conclusions. In fact we included a small number of studies with limited number of patients.

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**ICMJE CONFLICT OF INTEREST STATEMENT**

The authors declare no conflict of interest relevant to this work.

**FUNDING STATEMENT**

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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