Post-interventional Outcomes in the Management of Adult Calcaneonavicular Coalitions: A Systematic Review

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Abstract
Calcaneonavicular coalitions in adults can be managed conservatively or through operative means involving resection or arthrodesis of the joints. The aim of this systematic review was to compare complication rates and functional outcomes for the different interventions.

Introduction And Background
Introduction
Tarsal coalition is an abnormal connection between two or more tarsal bones due to a failure of segmentation of the primitive mesenchyme during the development of the foot [1]. The coalition may be fibrous (synodesmosis), cartilaginous (synchondrosis), or osseous (synostosis) and this disorder is inherited through an autosomal dominant pattern [2]. The true incidence of tarsal coalitions is unknown as only about 25% of individuals having tarsal coalition become symptomatic, require investigations, and pursue treatment [2]. A recent cadaveric study has shown an incidence as high as 13% of the population [3]. Although coalitions can occur between any tarsal bones, calcaneonavicular coalitions are the most frequent ones, accounting for 53% of tarsal coalitions [4].

The onset of symptoms in calcaneonavicular coalitions usually occurs between the ages of eight and 12 years when ossification takes place in the pre-existing fibrous coalition [1]. Commonly reported symptoms include anterolateral pain at the ankles, limitations in physical activity, and recurrent sprains to the ankle [5]. The first-line treatment for symptomatic tarsal coalitions is by conservative means. This is usually in the form of activity modification, non-steroidal anti-inflammatory drugs (NSAIDs) for pain relief, orthotics, or support via a walking boot or plaster [6]. However, if conservative measures fail, treatment is through surgical means by either open/arthroscopic resection of the coalition or arthrodesis where there is fusion of the affected joint [7,8]. These procedures are not independent of each other and in cases where resection has failed, patients may have an arthrodesis [7,8].

The literature indicates that surgical resection may be preferred in younger patients with calcaneonavicular coalitions with no evidence of arthritic changes or coalitions in other tarsal joints [9]. However, no literature has compared the effectiveness of the different interventions on an adult population nor looked at the complications patients may experience if they choose one intervention over the other. Adults differ from children in that their feet have achieved skeletal maturity and thus management may differ. Hence, this systematic review aims to compare the complication rates and functional outcomes for the different interventions used in treating calcaneonavicular coalitions in adults as reported in the existing literature.
**Methods**

A systematic search of the major databases - PubMed, MEDLINE, Embase, and the Cochrane Library - was conducted by two independent reviewers (HD and AD) in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The search terms used were "tarsal coalition," "calcaneonavicular coalition" and "outcome," "results," and "complications". The reference lists of included papers were further screened for eligible studies and a manual search of Google Scholar was also conducted. The last search of databases was conducted on February 19, 2021. Only studies with patients aged 16 years or older and published in English were included. Studies that included both patients younger and older than 16 years of age were also included but data was only extracted for those participants 16 years or older. Any disagreement regarding selection of studies was resolved by the general consensus of the two reviewers, and if required, the senior author (ME) was consulted.

Data extracted included patient demographics, number of coalitions, intervention, follow-up time, complications, mean pre-intervention, and post-intervention scores. For studies that did not include a scoring criterion, a symptom score, designed by the authors, was used to assess changes in symptoms and quality of life following intervention (Table 1). Studies were assigned a level of evidence as per the Centre of Evidence-Based Medicine (CEBM) classification [10]. The National Institutes of Health (NIH) "Quality Assessment Tool for case series studies" and the CEBM "Critical Appraisal of a Case Study tool" were used to assess risk of bias in the studies [11,12].

| Score | Extent of symptomatology         | Quality of life implication                                                                 |
|-------|----------------------------------|---------------------------------------------------------------------------------------------|
| 1     | Asymptomatic                     | Can carry out any activity with no limitation                                               |
| 2     | Mild symptomatology              | Small degree of activity limitation, i.e., in sports on exertion                            |
| 3     | Moderate symptomatology          | Fair degree of activity limitation, i.e., in day-to-day activities on exertion              |
| 4     | Severe symptomatology            | Substantial degree of activity limitation, i.e., in day-to-day activities without exertion  |
| 5     | Disabling symptomatology         | Disabling degree of activity limitation (cannot carry out any activity involving mobilization) |

**TABLE 1: Symptom score used to assess changes in symptoms and quality of life following intervention.**

The table is created by the authors of this study.

**Results**

**Study Selection**

The literature search identified 84 studies and after removing duplicates, the titles and abstracts of 52 studies were screened for. The full text of 36 studies was reviewed of which 23 studies met the inclusion criteria [13-35]. Screening of reference lists yielded no additional studies. Figure 1 summarizes the process of study selection.
All included studies were level 4 according to the CEBM classification [10]. Twelve of these studies were case reports [13-24], while 11 were case series [25-35], with a total of 97 patients (118 feet) treated for calcaneonavicular coalition, of these 41 patients were male and 56 were female. The mean age of included patients was 33.6 years with a range from 16 to 81 years. The mean follow-up time of patients post-intervention was 53 months. Table 2 summarizes the demographics of patients included in this study.

| Study                        | Design     | Level of evidence | Number of patients (number of feet) | Number of coalitions | Sex    | Average age in years (range) |
|------------------------------|------------|-------------------|------------------------------------|----------------------|--------|-----------------------------|
| Farid and Faber, 2019 [13]   | Case report| 4                 | 1 (2)                              | 2 CN                 | 1 female | 42                          |
| Watts et al., 2017 [14]      | Case report| 4                 | 1 (1)                              | 1 CN                 | 1 male   | 27                          |
| Lalli et al., 2014 [15]      | Case report| 4                 | 1 (1)                              | 1 CN                 | 1 male   | 50                          |
| Bauer et al., 2010 [16]      | Case report| 4                 | 1 (1)                              | 1 CN                 | 1 female | 27                          |
| Acabbo, 2009 [17]            | Case report| 4                 | 1 (1)                              | 1 CN                 | 1 female | 19                          |
| Pai et al., 2009 [18]        | Case report| 4                 | 1 (1)                              | 1 CN                 | 1 male   | 43                          |
| Efstathopoulos et al., 2006  | Case report| 4                 | 1 (1)                              | 1 CN                 | 1 male   | 25                          |
| Nilsson and Coetzee, 2006    | Case report| 4                 | 1 (1)                              | 1 CN                 | 1 male   | 47                          |
| Plotkin et al., 1996 [21]    | Case report| 4                 | 1 (2)                              | 2 CN                 | 1 male   | 17                          |
TABLE 2: Patient demographics for those included in this systematic review.

| Study                          | Type     | N  | CN  | Age Range |
|-------------------------------|----------|----|-----|-----------|
| Tanaka et al., 1995 [22]      | Case report | 4 | 1 (1) | 1 CN | 1 male | 23 |
| Richards et al., 1984 [23]    | Case report | 4 | 1 (2) | 2 CN | 1 male | 17 |
| Wray and Herndon, 1963 [24]   | Case report | 4 | 1 (2) | 2 CN | 1 male | 37 |
| Singh and Parsons, 2012 [25]  | Case series | 4 | 2 (2) | 2 CN | 2 males | 26 (24-27) |
| Scott and Tuten, 2007 [26]    | Case series | 4 | 7 (8) | 8 CN | 2 males, females | 41 (31-61) |
| Varner and Michelson, 2009 [27] | Case series | 4 | 14 (14) | 14 CN | N/A | 40 (16-81) |
| Fuson and Barrett, 1998 [28]  | Case series | 4 | 25 (28) | 28 CN | 7 males, 18 females | 41 (23-56) |
| Cohen et al., 1996 [29]       | Case series | 4 | 12 (13) | 13 CN | N/A | 33 (19-48) |
| Gonzalez and Kumar, 1990 [30] | Case series | 4 | 2 (4) | 4 CN | N/A | 17 (17) |
| O'Neill and Michell, 1989 [31] | Case series | 4 | 1 (2) | 2 CN | 1 male | 17 |
| Blockey, 1955 [32]            | Case series | 4 | 3 (3) | 3 CN | 3 males | 20 (17-26) |
| Cain and Hyman, 1978 [33]     | Case series | 4 | 3 (3) | 3 CN | 3 males | 20 (17-25) |
| Rankin and Baker, 1974 [34]   | Case series | 4 | 5 (7) | 7 CN | 5 males | 19 (17-22) |
| Heikel, 1962 [35]             | Case series | 4 | 11 (18) | 18 CN | 9 males, 2 females | 27 (16-63) |

**TABLE 2: Patient demographics for those included in this systematic review.**

CN: calcaneonavicular coalition

**Intervention**

Forty-seven calcaneonavicular coalitions were treated conservatively and this involved modification of activities, physiotherapy exercises, NSAIDs for pain relief, support via a cast, or a combination of the above. Seventy-one calcaneonavicular coalitions were treated operatively of those 62 were resection with or without interposition of soft tissue or bone wax, and nine were triple arthrodesis procedures.

**Post-intervention Complications**

The overall complication rate was 19.5% (n=23). Tables 3, 4 summarize the complications encountered in each study. The most common complication overall was pain which made up 48% (n=11) of all reported complications. This was followed by wound infection/necrosis and recurrence of the coalition, each making up 13% of reported complications (n=5). Other reported complications included talar fracture (n=2), gouty arthritis (n=1), and peroneal spasm (n=1).
| Study                          | Design     | Number of coalitions | Approach | Intervention                                      | Mean follow-up in months (range) | Complications | Scoring criteria | Mean pre-intervention score | Mean post-intervention score |
|-------------------------------|------------|----------------------|----------|--------------------------------------------------|---------------------------------|---------------|------------------|-----------------------------|------------------------------|
| Farid and Faber, 2019 [13]    | Case report| 2 CN                 | Conservative | Adjustment of activities                        | 12                              | None          | SS               | 3                           | 1                           |
| Watts et al., 2017 [14]       | Case report| 1 CN                 | Conservative | Walking boot                                    | 4                               | None          | SS               | N/A                         | 1                           |
| Lalli et al., 2014 [15]       | Case report| 1 CN                 | Operative   | En-bloc resection                               | 3                               | None          | SS               | 4                           | 1                           |
| Bauer et al., 2010 [16]       | Case report| 1 CN                 | Operative   | Arthroscopic resection                          | 24                              | None          | AOFAS            | 23/100                      | 32/100                       |
| Acabbo, 2009 [17]             | Case report| 1 CN                 | Conservative | Physiotherapy exercises, gait training, balance exercises | 2                               | None          | VAS              | 82/100                      | 0/10                         |
| Pai et al., 2009 [18]         | Case report| 1 CN                 | Conservative | Plaster                                         | 4                               | None          | SS               | 3                           | 1                           |
| Efstathopoulos et al., 2006 [19]| Case report| 1 CN                 | Operative   | Triple arthrodesia                              | 32                              | None          | SS               | 3                           | 1                           |
| Nilsson and Coetzee, 2006 [20]| Case report| 1 CN                 | Conservative | Low impact training                             | 6                               | None          | SS               | 4                           | 1                           |
| Plotkin et al., 1996 [21]     | Case report| 2 CN                 | Operative   | Triple arthrodesia                              | 36                              | None          | SS               | 4                           | 1                           |
| Tanaka et al., 1995 [22]      | Case report| 1 CN                 | Operative   | En-bloc resection                               | 27                              | None          | SS               | 4                           | 1                           |
| Richards et al., 1984 [23]    | Case report| 2 CN                 | Operative   | Talonavicular arthrodesia                        | N/A                             | Pain          | SS               | 4                           | 2                           |
| Wiley and Herndon, 1963 [24]  | Case report| 2 CN                 | Conservative | Longitudinal arch supports                      | N/A                             | N/A           | SS               | 4                           | 1                           |

**TABLE 3: Results of case reports on calcaneonavicular coalitions.**

SS: symptom score, AOFAS: American Orthopedic Foot and Ankle Society, VAS: visual analog scale
### TABLE 4: Results of case series on calcaneonavicular coalitions.

MOXFQ: Manchester Oxford Foot Questionnaire, VAS: visual analog scale, AOFAS: American Orthopedic Foot and Ankle Society, SS: symptom score, ROM: range of movement

| Study                      | Design | Number of coalitions | Approach | Intervention | Mean follow-up in months (range) | Complications                                                                 | Scoring criteria | Mean pre-intervention score | Mean post-intervention score |
|----------------------------|--------|----------------------|----------|--------------|----------------------------------|------------------------------------------------------------------------------|------------------|------------------------------|------------------------------|
| Singh and Parson, 2012     | Case series | 2 CN                | Operative | Arthroscopic resection | 6 (6)                           | None                                                                        | MOXFQ           | 78                           | 42                           |
| Scott and Tuten, 2007      | Case series | 8 CN                | Operative | En-bloc resection | 56.5 (39-84.5)                   | 1 superficial wound infection, 1 dysesthesia                                 | AOFAS           | N/A                          | 87 (79-97)                   |
| Varner and Michelson, 2000 | Case series | 10 CN               | Conservative | Cast immobilization, activity modification, and NSAIDs | 28 (4 to 82)                      | 1 peroneal spasm                                                            | SS              | 3                            | 2.1                          |
| Fuson and Barrett, 1998    | Case series | 4 CN                | Operative | 1 en-bloc resection, 3 arthrodesis | None                            | Good, fair, or poor                                                        | SS              | 3                            | 1                            |
| Cohen et al., 1996         | Case series | 2 CN                | Conservative | Activity modification, NSAIDs, and orthotics | 120 (120)                        | None                                                                        | Good, fair, or poor | N/A                          | 2 Good                       |
| Gonzalez and Kumar, 1990   | Case series | 13 CN               | Operative | En-bloc resection | 36 (17-94)                       | 1 reflex sympathetic dystrophy, 2 marginal wound necrosis, 2 required further arthrodesis | N/A             | 21 good, 1 fair, 4 poor      |
| O'Neill and Micheli, 1989  | Case series | 2 CN                | Operative | En-bloc resection | 95 (95)                          | 1 recurrence of bar                                                          | AOFAS           | 54                           | 74                           |
| Blockey, 1955              | Case series | 3 CN                | Conservative | Physiotherapy and physiotherapy | 24 (24)                          | 1 limited inversion, 2 rigidity and pain                                     | SS              | 4                            | 2                            |
| Cain and Hyman, 1978       | Case series | 3 CN                | Operative | En-bloc resection | 60 (60-60)                       | 1 pain                                                                      | SS              | 4                            | 1                            |
| Rankin and Bakar, 1974     | Case series | 7 CN                | Conservative | Rest or activity modification | 8 (8)                           | None                                                                        | SS              | 4                            | 1                            |
| Heikel, 1962 [35]          | Case series | 17 CN               | Conservative | Arch support and rest | 12 (6-18)                        | 1 pain                                                                      | Good, fair, or poor | N/A                          | 9 good, 1 poor               |
|                            | Case series | 1 CN                | Operative | Arthrodesis | 6 (6)                           | None                                                                        | N/A             | 1 good                       |

**Conservative vs Operative Complications**

The post-intervention complication rate in coalitions managed conservatively was significantly lower (10.6%) compared to those managed operatively (23.4%) and the difference was statistically significant ($\chi^2=3.90, p=0.048$). However, in both groups, pain remains the most commonly reported complication, reported in 6% (n=3) of interventions managed conservatively and 11% (n=8) of operative procedures. Other complications reported were peroneal spasm (n=1) and limited foot inversion (n=1) in interventions managed conservatively and wound infection (n=3), further arthrodesis required (n=3), talar fracture (n=2), gouty arthritis (n=1), and limited foot inversion (n=1) in operative procedures.
**Resection vs Arthrodesis Complications**

The complication rate of resection and arthrodesis were 27.4% and 11.1%, respectively. However, the difference in complication rates was not statistically significant (χ²=1.10, p=0.293). The only reported complication in arthrodesis was pain (n=1), but other complications reported in resection included wound infection (n=5), talar fracture (n=2), gouty arthritis (n=1), and limited foot inversion (n=1). It is worth noting that in studies where an arthroscopic resection was performed (n=3), there were no reported complications. However, in studies where open en-bloc resection was performed (n=59), complication rate was 28.8%. Again, the difference in complication rates between the two resection procedures was not statistically significant (χ²=0.85, p=0.355).

**Functional Outcomes**

A total of six scoring criteria were used to report the outcomes including the symptom score designed by the authors. Irrespective of the scoring criteria used or intervention, all studies reported an improvement in functional outcomes following intervention. The pre- and post-intervention outcome scores are also summarized in Tables 3, 4.

**Conservative vs Operative Outcomes**

There was a mean improvement in the symptom score by 1.85/5 in 27 studies that used a conservative intervention as compared to a mean improvement of 2.16/5 in 18 studies that used operative means of intervention. Where the VAS scoring criteria were used, the study by Acabbo which used a conservative approach reported an improvement by 8/10 whereas two studies where patients had operative interventions reported a mean improvement of 2/10 [17]. In studies that reported outcomes as good, fair, or poor, there were 11 good and one poor where conservative approaches were used (n=12) and 22 good, one fair, and four poor where operative approaches were used (n=27).

**Resection vs Arthrodesis Outcomes**

The mean improvement in symptom score for studies with resection was 2.1/5 (n=10), as compared to 2.3/5 for studies where a triple arthrodesis was performed (n=8). There were 21 good, one fair, and four poor outcomes reported in studies with resection and one good outcome reported in the study by Heikel where a triple arthrodesis was performed and such a scoring criterion was used [35]. Other scoring criteria used in studies with resection were the AOFAS with a mean improvement of 40.5/100, the MOXFQ with a mean improvement of 36/100, and the VAS criteria with a mean improvement of 5/10. Cohen et al. also reported an average improvement in range of ankle movement by 10.8° in 13 patients where resection was performed [29].

**Risk of Bias**

A summary of risk of bias assessment is outlined in Table 5 and Table 6 for case reports and case series, respectively. Two case reports had a quality rating of "good," seven "fair," and three "poor" as per the CEBM guidelines [12]. Three case series had a quality rating of "good," six "fair," and two "poor" as per the NIH quality rating tool [11].
| Study                        | Did the study address a clearly focused question /issue? | Is the research method (study design) appropriate for answering the research question? | Are both the setting and the subjects representative with regard to the population to which the findings will be referred? | Is the researcher’s perspective clearly described and taken into account? | Are the methods for collecting data clearly described? | Are the methods for analyzing the data likely to be valid and reliable? Are quality control measures used? | Was the analysis repeated by more than one researcher to ensure reliability? | Are the conclusions drawn justified by the results? | Are the findings of the study transferable to other settings? | Overall quality rating |
|-----------------------------|-----------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|-----------------------------------------------------------------|---------------------------------------------------------------------------------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------|
| Farid and Faber, 2019 [13]  | Yes                                                       | Yes                                                                                  | Yes                                                                                              | NA                                                                            | Yes                                                             | Yes                                                                              | Yes                                                                              | Yes                                                                              | Yes                                                                                     | Fair                     |
| Watts et al., 2017 [14]     | Yes                                                       | Yes                                                                                  | Yes                                                                                              | NA                                                                            | Yes                                                             | Yes                                                                              | Yes                                                                              | Yes                                                                              | Yes                                                                                     | Fair                     |
| Lall et al., 2014 [15]      | Yes                                                       | Yes                                                                                  | Yes                                                                                              | NA                                                                            | Yes                                                             | Yes                                                                              | Yes                                                                              | Yes                                                                              | Yes                                                                                     | Fair                     |
| Bower et al., 2010 [16]     | Yes                                                       | Yes                                                                                  | Yes                                                                                              | Yes                                                                            | Yes                                                             | Yes                                                                              | Yes                                                                              | Yes                                                                              | Yes                                                                                     | Good                    |
| Acabno, 2009 [17]           | Yes                                                       | Yes                                                                                  | Yes                                                                                              | Yes                                                                            | Yes                                                             | Yes                                                                              | Yes                                                                              | Yes                                                                              | Yes                                                                                     | Good                    |
| Poi et al., 2009 [18]       | Yes                                                       | Yes                                                                                  | Yes                                                                                              | Yes                                                                            | Yes                                                             | Yes                                                                              | Yes                                                                              | Yes                                                                              | Yes                                                                                     | Fair                    |
| Efstathopoulos et al., 2006 | Yes                                                       | Yes                                                                                  | Yes                                                                                              | NA                                                                            | Yes                                                             | NA                                                                               | Yes                                                                              | Yes                                                                              | Yes                                                                                     | Fair                    |
| Nilsson and Coetzee, 2006   | Yes                                                       | Yes                                                                                  | Yes                                                                                              | NA                                                                            | Yes                                                             | Yes                                                                              | Yes                                                                              | Yes                                                                              | Yes                                                                                     | Fair                    |
| Plotkin et al., 1995 [21]   | Yes                                                       | Yes                                                                                  | Yes                                                                                              | NA                                                                            | Yes                                                             | Yes                                                                              | Ns                                                                               | Yes                                                                              | Yes                                                                                     | Poor                     |
| Takeda et al., 1995 [22]    | Yes                                                       | Yes                                                                                  | Yes                                                                                              | NA                                                                            | Yes                                                             | Yes                                                                              | Yes                                                                              | Yes                                                                              | Yes                                                                                     | Fair                    |
| Richards et al., 1984 [23]  | Yes                                                       | Yes                                                                                  | Yes                                                                                              | NA                                                                            | Yes                                                             | Yes                                                                              | Ns                                                                               | Yes                                                                              | Yes                                                                                     | Poor                    |
| Wray and Herndon, 1963 [24] | Yes                                                       | Yes                                                                                  | Yes                                                                                              | NA                                                                            | Yes                                                             | Yes                                                                              | Ns                                                                               | Yes                                                                              | Yes                                                                                     | Poor                    |

**TABLE 5: Critical appraisal of case reports.**
| Study                        | Was the study question or objective clearly stated? | Was the study population clearly and fully described, including a case definition? | Were the cases consecutive? | Were the subjects comparable? | Were the intervention clearly described? | Were the outcome measures clearly defined, valid, reliable, and implemented consistently across all study participants? | Was the length of follow-up adequate? | Were the statistical methods well-described? | Were the results well-described? | Overall quality rating |
|-----------------------------|---------------------------------------------------|-------------------------------------------------------------------------------|----------------------------|--------------------------------|----------------------------------------|------------------------------------------------------------------------------------------|----------------------------------|-------------------------------|--------------------------------------|------------------------------|
| Singh and Parsons, 2012 [25]| Yes                                               | Yes                                                                            | No                         | No                             | Yes                                    | Yes                                                                                      | No                               | Yes                           | Yes                                  | Poor                         |
| Scott and Tuten, 2007 [26]  | Yes                                               | Yes                                                                            | Yes                        | Yes                            | Yes                                    | Yes                                                                                      | Yes                              | Yes                           | Yes                                  | Good                         |
| Varner and Michelson, 2000 [27]| Yes                                               | No                                                                             | Yes                        | Yes                            | Yes                                    | Yes                                                                                      | Yes                              | No                            | Yes                                  | Fair                         |
| Fuson and Barnett, 1998 [28]| Yes                                               | Yes                                                                            | Yes                        | Yes                            | Yes                                    | Yes                                                                                      | Yes                              | No                            | Yes                                  | Fair                         |
| O'Neill and Micheli, 1989 [30]| Yes                                               | Yes                                                                            | Yes                        | Yes                            | Yes                                    | Yes                                                                                      | Yes                              | No                            | Yes                                  | Good                         |
| Blockey, 1955 [31]          | Yes                                               | Yes                                                                            | No                         | No                             | Yes                                    | Yes                                                                                      | No                               | No                            | Yes                                  | Fair                         |
| Cain and Hyman, 1978 [32]   | Yes                                               | Yes                                                                            | No                         | No                             | Yes                                    | Yes                                                                                      | No                               | No                            | Yes                                  | Fair                         |
| Rankin and Baker, 1974 [34] | Yes                                               | Yes                                                                            | No                         | No                             | Yes                                    | Yes                                                                                      | No                               | No                            | Yes                                  | Poor                         |
| Helland, 1962 [35]          | Yes                                               | Yes                                                                            | No                         | No                             | Yes                                    | Yes                                                                                      | Yes                              | No                            | Yes                                  | Fair                         |

**TABLE 6: Critical appraisal of case series.**

**Discussions**

This study is the first systematic review of the literature to assess complication rates and changes in patient-reported outcome scores following intervention in the management of calcaneonavicular coalitions in the adult population. The overall complication rate following intervention was 19.5% and all studies reported an improvement in outcome scores following intervention regardless of whether a conservative or operative approach was used.

The most commonly reported complication post-intervention was pain, reported in 48% of cases. The results of our study show that patients who were subject to an operative procedure were significantly more likely to encounter complications post-intervention as opposed to those where a conservative means of treatment was used. This, therefore, supports the general consensus that calcaneonavicular coalitions should be managed conservatively and operative procedures attempted only if the former fails [6-8]. There was no identifiable difference in complication rates between resection and arthrodesis nor between open and arthroscopic resection. However, marginal wound necrosis, a major complication, was reported by Cohen et al. only when extensor digitorum brevis (EDB) interposition was attempted following open en-bloc resection of the coalition to prevent reoccurrence. Cohen et al. believe that this may have been caused by an increased area of dead space created by transfer of the muscle leading to necrosis. This complication was not
reported again once the technique of EDB interposition was discontinued on the remaining patients operated upon in their study [39]. Patients who had an arthroscopic resection, a relatively new technique first attempted by Lui et al. in 2006, reported no complications as opposed to those who had an open resection [36]. The potential advantages of this technique over open surgery include a swifter post-operative recovery, reduced post-operative pain, more aesthetically appealing for the patient, and lower rates of infection [37].

The first line treatment for calcaneonavicular coalitions is conservative management followed by operative means if there is no improvement [6]. It is generally agreed that resection of the coalition is more suitable unless there is evidence of further coalitions or arthritic changes in the joints [9]. In those cases, or where resection has failed, arthrodesis is recommended [7,8]. In all studies included in this systematic review, the recommended order of treatment was followed except in the study by Tanaka et al. where conservative treatment was not attempted because the patient wanted an early recovery [22]. The improvement in functional outcome scores for all patients in our review was similar between conservative vs operative and resection vs arthrodesis. However, it was difficult to undertake further analysis given the difference in scoring systems used throughout.

Following early reports of recurrence rates as high as 30% in patients having open en-bloc resection of tarsal coalitions, the concept of tissue interposition at the site of resection became popular [38]. Muheb et al. reported a reduction in calcaneonavicular recurrence to 13% when a fat graft was interposed at site of resection [9]. Similarly, Masquijo et al. reported a recurrence rate of 4% with fat graft, 6% with bone wax, and 40% with EDB interposition [39]. However, both these studies were conducted on a pediatric population, and to date, there is no agreed consensus on the effectiveness of using grafts in an adult population. Hence, our review included a mixture of both patients who had a graft interposition and those that did not. In a systematic review comparing arthroscopic resection of tarsal coalitions, Malik-Tabassum et al. suggest that arthroscopic procedures may also reduce rates of recurrence due to earlier mobilization and weight-bearing post-operatively, inhibiting re-ossification at the site of resection [5]. This however remains to be proven by future studies.

There are several limitations to our study. Most notably, the review only consisted of studies with level 4 tier of evidence and did not identify any randomized control or comparative studies. However, this is due to the paucity of literature surrounding the topic. Furthermore, given the heterogeneity in scoring criteria used in included studies, further statistical analysis on improvement in functional outcome post-intervention was not possible. Lastly, human factors such as the surgeon’s experience in undertaking tarsal resection or arthrodesis should be taken into account when considering post-operative complications or outcomes. This would be difficult to quantify but may be worth taken into consideration.

The strengths of this study are its use of a systematic methodology with a comprehensive database search and vigorous quality assessment of included studies. To date, it remains the first systematic review to assess complications and functional outcomes in the management of calcaneonavicular coalitions within an adult population.

This study has identified the need for further research in the management of adults presenting with calcaneonavicular coalitions. Given that such presentation is relatively less common than in children, it is not surprising that majority of the existing literature are on a pediatric population. However, management and complication rates may differ, hence the need for prospective trials with comparable patient-reported functional outcome scores and follow-up time.

**Conclusions**

Conservative management of calcaneonavicular coalitions in adults should continue to be advocated as first-line treatment due to a significantly lower post-intervention complication rate compared to operative procedures. Complication rates following surgery were similar in resection and arthrodesis. Both conservative and operative interventions reported similar improvement in patient-reported functional outcome scores. Future studies on the management of calcaneonavicular coalitions in adults are warranted.

**Additional Information**

**Disclosures**

**Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.
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