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Open versus Minimal Invasive Curettage in Simple Bone Cyst: A Systematic Review

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ABSTRACT

Introduction: Open curettage is the standard surgical procedure for simple bone cyst. However, this procedure has some disadvantages so that minimal invasive curettage becomes one of the treatment alternatives.
Method: A systematic search was conducted through PubMed, Google Scholar, and Cochrane Library. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were used.
Result: A total of three studies were included. Total sample size ranged from 16-40 patients, aged ranged from 4-28 years, and 64 males and 18 females were examined.
Discussion: Open curettage was inferior to minimal invasive curettage in terms of mean hospital stay (4,7 vs 2,2 days, $p < 0,01$), time to full weight bearing (17,0 vs 4,0 days, $p < 0,01$), time to return to sport activities (14,5 vs 6,5 weeks, $p < 0,01$), time to solid union (6,6 - 12,2 vs 3,7 months, $p < 0,05$), AOFAS scale (96,1 vs 97,5, $p > 0,05$), time to complete radiological healing (12,8 vs 14,6 weeks, $p > 0,05$), Chang's radiological evaluation (14/19 vs 11/12 healed, $p > 0,05$), and number of complications (1 sural neuritis, 1 CPC leakage vs 0 complication, $p > 0,05$). However, mean operating time was found to be inconsistent between studies and mean number of procedures and recurrence were relatively same in both groups.
Conclusion: This study report that minimal invasive curettage is superior to open curettage. Further study with higher amount of included studies and sample size is needed.

Keywords: open curettage, minimal invasive curettage, simple bone cyst

INTRODUCTION

A simple bone cyst (SBC) is a unilocular bone cyst containing serous or serousanguineous fluid. It is also known as unicameral bone cyst and was first reported by Virchow in 1876.[1]

Until recently, etiology of simple bone cyst remains unknown yet venous obstruction theory is one of the most common accepted pathogenesis models. Almost 85% of SBC occurs at less than 20 years old and most commonly affect boys rather than girls (3:1).[2] The common sites of occurrence are metaphyseal-diaphyseal region of long bones especially in humerus and femur.[1] Other than that, it can occurs at flat bones such as calcaneus and pelvic.[2]

Sign and symptoms of SBC varied from pain, swelling, until in some cases, pathological fracture.[2] Treatment of SBC aims at preventing pathological fracture, promoting healing of cyst, preventing recurrence and fracture. The treatment consists of non operative (immobilization alone, aspiration/ methylprednisolone acetate injection) and operative (open or minimal invasive curettage and bone grafting with or without internal fixation).[3] Even though the standard conventional surgical procedure, open curettage followed by bone grafting, provide good outcome, this procedure requires restriction of weight bearing for several weeks.[4] This condition certainly disturbs patients, the majority of whom are children to young adults. Therefore, recently, minimal invasive curettage becomes one of SBC treatment options.

The purpose of this study is to compare between open curettage and minimal invasive curettage measured with both clinical (mean operating time, mean hospital stay, AOFAS ankle/hindfoot scale, recurrence, time to full weight bearing, time to return to sport activities, complications, time to solid union, success rate, mean number of procedure) and radiological (Chang's radiological evaluation, complete radiological healing) outcomes.

MATERIALS AND METHODS

Searching Strategy

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) criteria were used to perform the systematic review. A thorough literature search was conducted to find a full-length, peer-reviewed study in English comparing the clinical and radiological outcomes of open curettage versus minimal invasive curettage for the treatment of SBC. We used PubMed, Google Scholar, and the Cochrane Library to conduct our research and identify relevant articles which was searched up to April 2022 using keywords "open curettage", "endoscopic curettage", “open surgery”, “endoscopic surgery”, “minimal invasive”, “bone cyst”, “simple bone cyst”, and “unicameral bone cyst” (Figure 1).

Inclusion Criteria

Those data were manually scanned and reviewed with inclusion criteria as follows: (1) the studies included a comparative design for open versus minimal invasive curettage for simple bone cyst, (2) patients diagnosed with simple bone cyst of any locations, (3) studies clearly report either clinical or radiological outcomes or both. Exclusion criteria were other bone tumor and tumor-like lesion other than SBC, infection, deformity, noncomparative studies, nonhuman in vivo and in vitro studies, and studies comparing treatment options other than open and minimal invasive curettage.

Evaluation of Quality

Study quality and risk of bias were assessed using criteria published by the Oxford Center for Evidence-based Medicine, perspicacity as defined by the GRADE Working Group, and sanction by the Agency for Healthcare Research and Quality (AHRQ). While the evidence is divided into four categories: "class I" for high-quality RCTs, "class II" for moderate to low-quality RCTs and good-quality cohorts, "class III" for moderate or low-quality cohorts and case-control studies, and "class IV" for case series.

RESULTS

Literature search, Study selection and Study Characteristics

From multiple databases, the electronic search yielded 54 records. After removing the duplication, 41 records were obtained. 38 records were then excluded based on title screening. The remaining three studies were included in qualitative and quantitative synthesis after the identification, screening, eligibility, duplicate elimination, and exclusion processes. The remaining publications were removed from the study because they did not meet the inclusion or meet the exclusion criteria.

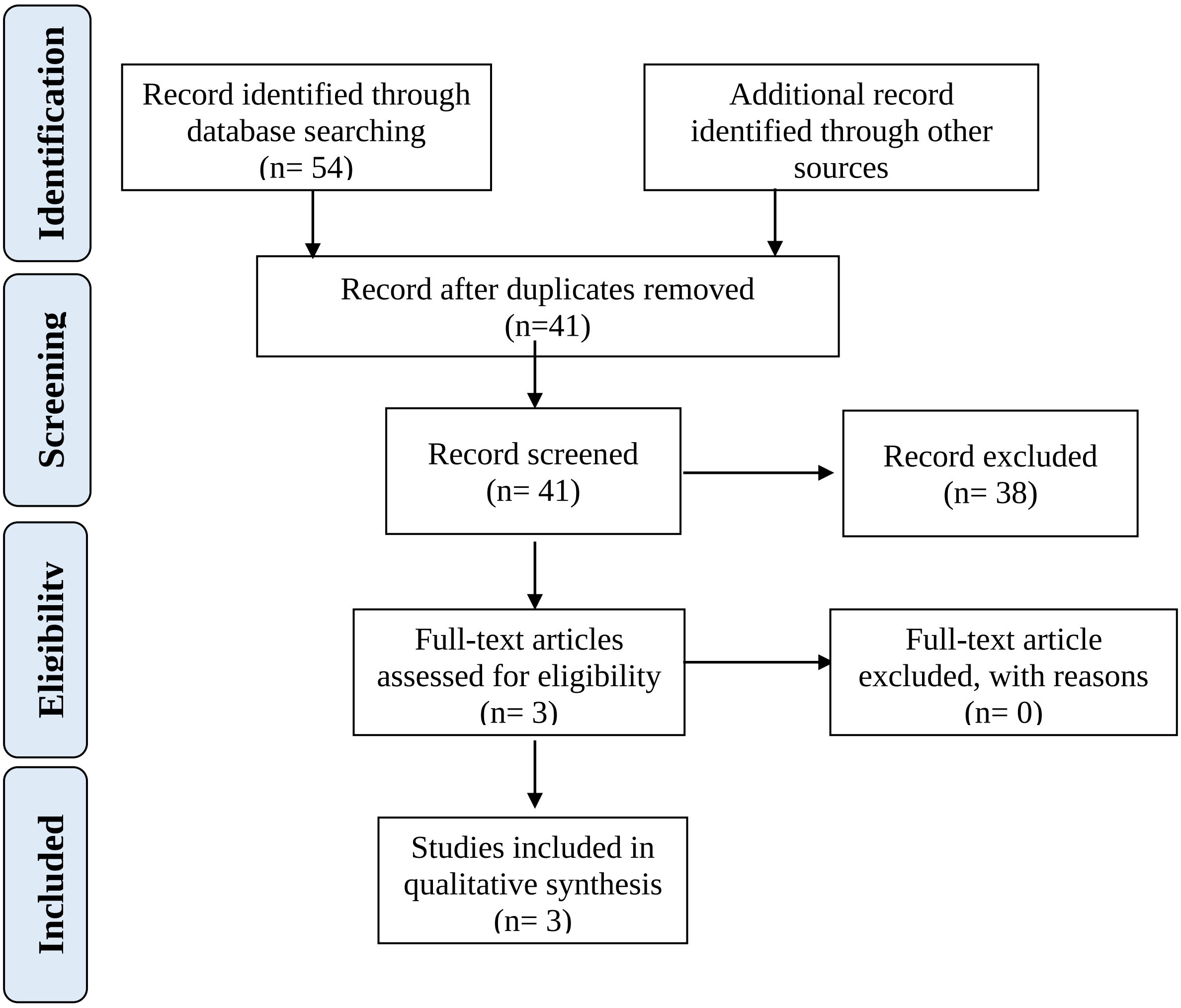

Figure 1. PRISMA Flow Chart

In this systematic review, one study used a prospective cohort study and two studies used retrospective study design. Sample size ranged from 16-40 patients. Participants aged ranged from 4-28 years, and in total 64 males and 18 females were examined. All these patients were followed up around 18 – 84 months.

Table 1 and 2 presents the key characteristic of the included studies along with the level of evidence. Table 3 presents the outcome assessed and the complication among three studies. In specific, table 4 provide detail information's regarding each outcome characteristics in all included studies.

Table 1. Characteristic of the studies

No.	Reference	Journal	Study Design	Level of Evidence
1	Hou et al., 2010	The Journal of Bone and Joint Surgery	Retrospective comparative study	III
2	Yildirim et al., 2011	The Journal of Bone and Joint Surgery	Prospective cohort study	II
3	Nishimura et al., 2016	The Journal of Foot and Ankle Surgery	Retrospective case control study	III

Table 2. Characteristic of the study populations

No.	Reference	Total Sample Size	Mean Age (Age range in year)	Male	Female	Study Comparison	Surgical Technique
1.	Hou et al., 2010	40 patients	13,2 years old (range 4 – 27 years old)	30 male	10 female	To compare: Serial percutaneous steroid and autogenous bone-marrow injection (Group 1, 9 patients) Open curettage and grafting with a calcium sulfate bone substitue either without instrumentation (Group 2, 12 patients) or with internal instrumentation (Group 3, 7 patients) Minimal invasive curettage, ethanol cauterization, disruption of cystic boundary, insertion of a synthetic calcium sulfate bone-graft substitute, and placement of a cannulated screw to provide drainage (Group 4, 12 patients) In the treatment of unicameral bone cyst.	Serial percutaneous steroid and autogenous bone-marrow injections 3 consecutive times within 2 months (Group 1) Open curettage and grafting with calcium sulfate pellets alone (Group 2) Open curettage, grafting with calcium sulfate pellets, and internal fixation with a dynamic compression plate or compression hip screw to fix a displaced fracture (Group 3). Minimal invasive procedure through small skin incision, with open curettage, ethanol cauterization, disruption of cystic lining, grafting with calcium sulfate pellets placed through small cortical fenestration, and insertion of cannulated screw. > (In details) (minimal-incision open curettage) Small logitunidal skin incision (< 1 cm in upper extremity, < 2 cm in lower extremity) was made, small fenestration was created in the cortex with the use of a small (4 mm-diameter) trephine through the thinnest part of the part of the cyst wall at the level of midpoint of the cyst. Cyst content were aspirated and special designed curved impactors were used to break up any septa within the cyst. The membrane lining the cyst then removed with the use of curved curet inserted through the fenestration. Fluoroscopy may be used if cyst was large and eradication of cyst was questionable. To avoid recurence, 95% ethanol solution was injected to fill the cyst. Ethanol was left in place for 30 seconds, then aspirated. This was followerd by extensive irrigation with normal saline to minimize damage to healthy tissue. Following irrigation, curved impactor was inserted and used to penetrate the boundary between cyst and normal bone marrow space. A cyst-and-medullary canal

							communication allows introduction of bone marrow cells into the cyst. Calcium sulfate bone-graft was then filled into the cyst with the use of curved impactors. Finally, one 4,5-mm cannulated screw was inserted throug small fenestration to ptovide continous decompression. (Group 4).
2.	Yildirim et al., 2011	26 patients (13 patients with traditional open curettage (group 1) and 13 patients with percutneous endoscopic curettage (group 2))	22,9 years old (range 18 – 28)	26 males	(-)	Open versus endoscopic curettage and grafting for simple calcaneal bone cyst	Group 1 (Open): The patient is placed in the supine position on the operating table with a sandbag under the ipsilateral hip. For those in group 1, an open lateral approach is made to expose the wall of the cyst. A cortical window is removed and the cyst debrided with curettes and washed out with saline solution. Corticocancellous allograft chips (TranZgraft; Tissue Banks International (TBI), Baltimore, Maryland) are introduced. Group 2 (Endoscopic – MI): A is placed on the lateral side of the hindfoot under fluoroscopic control to locate the cyst exactly (Fig. 1). The viewing portal incision is made at the lateral aspect of the calcaneum, centred directly over the cyst (Fig. 2). A blunt trocar is then introduced through the lateral wall of the calcaneum. A 4.0 mm, 30° arthroscope is inserted into the cyst to visualise its contents (Fig. 3). Next, a second portal is created approximately 2 cm anterior to the viewing portal (Fig. 4 and 5). The contents of the cyst are evacuated through this portal, and tissue is procured for biopsy. A 30° arthroscope is used for visualisation of the cavity (Fig. 6), and to allow guided curettage with a shaver, followed once more by the introduction of corticocancellous allograft chips (Fig. 7). A below-knee cast was retained for all patients in both groups for three weeks. Partial weightbearing was allowed as tolerated for the next three weeks and then full weight-bearing.
3.	Nishimura et al., 2016	16 patients (8 with open procedure (O group), 8 with	13 $\pm$ 3,2 years old	3 males (O group)	5 females	Endoscopic versus open surgery for calcaneal bone cyst	O Group (Open): The open surgical technique was performed with the patient under lumbar spinal anesthesia and in the

		endoscopic procedure (E group))	(O group) 13,3 ± 2,6 years old (E group)	5 males (E group)	(O group) 3 females (E group)		lateral decubitus position, with application of a pneumatic tourniquet. Skin incisions were made just on the lateral aspect of the calcaneal cyst. The peroneal tendon sheath was opened, and the peroneal tendons were retracted downward. Round-shaped bone windows, 10 mm - 15 mm, were made at the lateral wall of the cyst using a surgical air tome. After histologic diagnosis of membrane-like soft tissues of the inner wall was confirmed by rapid histologic examination, the membranous lesions were curetted through the bone windows. Calcium Phosphate Cement (CPC) was prepared as described for the endoscopic surgical technique. The CPC was injected into the bone defect, and the lateral wall of the bone defect was reconstructed with the removed cortical bone, although sometimes this wall was too thin to be returned (in such cases, the defects were covered with just the soft tissues). E Group (Endoscopic – MI): Surgery was performed with the patient under lumbar spinal anesthesia and in the lateral decubitus position, with application of a pneumatic tourniquet. Before making a skin incision, the configuration of the calcaneal cyst was confirmed under image intensifier guidance from the lateral aspect of the heel, and the location of the peroneal tendons was confirmed by ultrasonography. Two skin incisions were made on the lateral aspect of the most anterior and posterior points of the calcaneal cyst, avoiding the peroneal tendons based on the ultrasonography findings. The lateral calcaneal wall was fenestrated at 2 points using a 4.5-mm drill. A 2.5-mm arthroscope was then inserted by way of a bone hole. Clear yellow fluid was found in the cyst, and the fluid was aspirated. The inner wall was often lined with a membrane-like soft tissue. After a detailed inspection of the cyst structure, a biopsy specimen of this membrane-like soft tissue was obtained for rapid histologic examination. After pathologic diagnosis, the inner

							wall soft tissue was resected using a small suction shaver, an abrader, and a small curette (Fig. 2C). Calcium phosphate cement (CPC; Biopex, HOYA Technosurgical Corporation, Tokyo, Japan) was prepared by mixing the composite powder and solvent in a special syringe and then injected using a cement gun. Once the composite powder and solvent had been mixed, the CPC requires approximately 10 minutes to harden. It reaches maximum strength (70 to 85 MPa) within only about 3 days after injection and hardens enough to allow full weightbearing. After the irrigation fluid was aspirated, the CPC was injected by way of 1 of the 2 drill holes.

Table 3. Summary of outcomes

No.	**Reference**	**Study Comparison**	**Follow-Up Duration**	**Clinical outcomes**	**Complications**
1.	Hou et al., 2010	To compare: Serial percutaneous steroid and autogenous bone-marrow injection (Group 1, 9 patients) Open curettage and grafting with a calcium sulfate bone substitue either without instrumentation (Group 2, 12 patients) or with internal instrumentation (Group 3, 7 patients) Minimal invasive curettage, ethanol cauterization, disruption of cystic boundary, insertion of a synthetic calcium sulfate bone-graft substitute, and placement of a cannulated screw to provide drainage (Group 4, 12 patients) In the treatment of unicameral bone cyst.	18 – 84 months	Chang's radiological result, mean time to solid union, success rate, mean number of procedure	N/A
2.	Yildirim et al., 2011	Open versus endoscopic curettage and grafting for simple calcaneal bone cyst	28,7 months (24 – 36 months)	Mean operating time, mean hospital stay, complete radiological healing, Chang's radiological result	(-)
3.	Nishimura et al., 2016	Endoscopic versus open surgery for calcaneal bone cyst	44,3 $\pm$ 23,2 months (O Group)	Mean operating time, AOFAS ankle/hindfoot scale, recurrence, time to full weight bearing, time to return to sports activities, complications	2 complications (1 sural neuritis, 1 CPC leakage) in O Group. No complication found in E group.

			26,9 ± 4,1 months (E Group)		

Table 4. Characteristic of Study Outcomes

No	Reference	Outcome Measure			
		Chang's Radiological Evaluation	**Time to Solid Union (Months)**	**Success Rate (No with healing/no in group)**	**Mean Number of Procedure**
1.	Hou et al., 2010	Group 1 (Serial percutaneous injection) (n=9) Healed: 3 (33,3%) Persistent cyst:1 (11,1%) Recurrent cyst: 4 (44,4%) Group 2 (Open + Pellets alone) (n=12) Healed: 8 (66,6%) Persistent cyst:1 (11,1%) Recurrent cyst: 3 (25%) Group 3 (Open + pellets + internal fixation (IF)) (n=7) Healed: 4 (57,1%) Healed with defect: 2 (28,5%) Persistent cyst:1 (14,2%) Group 4 (MI) (n=12) Healed: 7 (58,3%) Healed with defect: 4 (33,3%)	Group 1 (Serial percutaneous injection): 23,4 ± 14,9 Group 2 (Open + Pellets alone): 12,2 ± 8,5 Group 3 (Open + pellets + internal fixation (IF)): 6,6 ± 4,3 Group 4 (MI): 3,7 ± 2,3	Group 1 (Serial percutaneous injection): 3/9 Group 2 (Open + Pellets alone): 8/12 Group 3 (Open + pellets + internal fixation (IF)): 6/7 Group 4 (MI): 11/12	Group 1 (Serial percutaneous injection): 4 Group 2 (Open + Pellets alone): 1,6 Group 3 (Open + pellets + internal fixation (IF)): 2,1 Group 4 (MI): 2,1

No	Reference	Outcome Measure			
		Mean Operating Time (Minutes)	**Mean Hospital Stay (Days)**	**Complete Radiological Healing (Weeks)**	**Chang's Radiological Evaluation**
2.	Yildirim et al., 2011	Group 1 (Open): 67,3 (60 – 75) Group 2 (Endoscopic – MI): 45 (40 – 50) Statistical significant difference (p < 0,01)	Group 1 (Open): 4,7 (4 – 6) Group 2 (Endoscopic – MI): 2,2 (2 – 3) Statistical significant difference (p < 0,01)	Group 1 (Open): 14,6 (12 – 32) Group 2 (Endoscopic – MI): 12,8 (12 – 15) No statistical significant difference (p = 0,345)	Group 1 (Open) (n=13): Healed: 9 Healing with defects: 3 Persistent cyst: 1 Therefore, overall radiological success rated = 92,3%

					Group 2 (Endoscopic – MI) (n=13): Healed: 11 Healing with defects: 2 Therefore, overall radiological success rated = 100%

No	**References**	**Outcome Measure**					
		Mean Operating Time (Minutes)	**AOFAS ankle/hindfoot scale (Last follow up visit)**	**Recurrence**	**Time to full weightbearing (Days)**	**Time to return to sport activities (Weeks)**	**Complications**
3.	Nishimura et al., 2016	O Group (Open): 53,5 ± 6,5 E Group (Endoscopic – MI): 56,1 ± 13,8 No statistical significant difference (p = 0,613)	O Group (Open): 96,1 ± 6,6 E Group (Endoscopic – MI): 97,5 ± 5,6 No statistical significant difference (p = 0,568)	O Group (Open): 0 E Group (Endoscopic – MI): 0	O Group (Open): 17,0 ± 3,6 E Group (Endoscopic – MI): 4,0 ± 1,0 Statistical significant difference (p < 0,001)	O Group (Open): 14,5 ± 0,9 E Group (Endoscopic – MI): 6,5 ± 1,1 Statistical significant difference (p < 0,001)	O Group (Open): 2 (sural neuritis 1 patients, CPC leakage 1 patients) E Group (Endoscopic – MI): 0 Statistical significant difference (p = 0,131)

DISCUSSION

There are several treatment options for SBC. We aimed to achieve least complication and best clinical and radiological outcome. In this systematic review, we compared surgical treatment between open and minimal invasive curettage by assessing both clinical and radiological outcome. The clinical outcome was assessed using mean operating time, mean hospital stay, AOFAS ankle/hindfoot scale, recurrence, time to full weight bearing, time to return to sport activities, complications, time to solid union, success rate, mean number of procedure, meanwhile radiological outcome was assessed using Chang's radiological evaluation and complete radiological healing.

Two studies compared mean operating time between open and minimal invasive curettage. Study conducted by Yildirim et al. (2011) found that mean operating time was significantly longer for the patient treated by open curettage (67,3 minutes (60 – 75 minutes)) as compared to those treated by minimal invasive curettage (45 minutes (40 – 50 minutes)) ($p < 0{,}01$).[5] On the contrary, study conducted by Nishimura et al. (2016) showed that operative time was shorter in open curettage than in minimal invasive curettage (53,5 $\pm$ 6,5 versus 56,1 $\pm$ 13,8 minutes). In statistical analysis, this finding was not statistically significant ($p = 0{,}613$).[4] From both studies, we can observe that the result was inconsistent. Therefore, we cannot conclude which operative methods was better in terms of mean operating time.

The other outcomes that can be used to compare open and minimal invasive curettage was Chang's radiological evaluation. Two among three studies evaluated Chang's radiological evaluation. Hou et al. (2010), reported that in open curettage group (in both with and without instrumentation groups), 12 patients healed, 2 patients healed with defect, 2 patients had persistent cyst, and 3 patients had recurrent cyst. The radiological healing success rate in this group was 73,68% (14 healed out of 19 patients). Meanwhile in minimal invasive curettage group, the radiological healing success rate was 91,67% (11 healed out of 12 patients). Specifically, 7 patients healed without defect and 4 patients healed with defect.[1] The other study that evaluated Chang's radiological evaluation as an outcome was the study conducted by Yildirim et al. (2011). Yildirim et al. found that 9 patients healed, 3 patients healed with defects and 1 patients with persistent cyst. In this group, the overall radiological success rate was 92,3% (12 healed out of 13 patients) as compared to 100% in the minimal invasive curettage group (13 healed out of 13 patients). Statistical analysis was not conducted in both studies yet we can observe that percentage difference of radiological healing success rate was quite significant between open and minimal invasive curettage group. In conclusion, from Chang's radiological evaluation, minimal invasive curettage is superior to open curettage.[5]

The other outcomes were also measured by three of the studies. Unfortunately, none of them intersected to compare between one study to another. Therefore, we would like to review it based on the outcome in each study. Time to solid union was reported by Hou et al. (2010). In this study, mean time to solid union in open curettage group (in both with and without instrumentation) ranged from 6,6 $\pm$ 4,3 to 12,2 $\pm$ 8,5 as compared to minimal invasive curettage group 3,7 $\pm$ 2,3 months. In addition, to this, Kaplan-Meier survival curves was measured and found that minimal invasive curettage had significantly shortest time to solid union as compared with the other groups. In addition to this, mean number of procedures was reported. The mean number of procedures in open curettage group ranged from 1,6 – 2,1 as compared to 2,1 in minimal invasive curettage group. There was no statistical analysis conducted in this study to define statistical significancy.[1]

The other study conducted by Yildirim et al. (2011) compared open curettage to minimal invasive curettage using mean hospital stay and time to complete radiological healing. The mean hospital stay was significantly longer in open curettage group (4,7 days (4-6)) as compared to 2,2 days (2 – 3); p < 0,01) in minimal invasive curettage group. Besides, this study also found evidence favoring minimal invasive curettage in which the cyst showed complete radiological evidence of healing at 12,8 weeks (12 – 15) as compared to 14,6 weeks (12 -32) for open curettage. However, this comparison was not statistically significant.[5]

The most recent study conducted in 2016 by Nishimura et al. reported such clinical outcomes as AOFAS ankle/hindfoot scale, recurrence, time to full weight bearing, time to return to sports activities, and the occurrence of complications. AOFAS ankle/hindfoot scale, showed that open curettage had lower score than minimal invasive curettage (96,1 $\pm$ 6,6 vs 97,5 $\pm$ 5,6). This result was not statistically significant with p value = 0,568. There was no recurrence in both groups. Both time to full weight bearing and time to return to sport activities was significantly longer in open curettage group (17,0 $\pm$ 3,6 versus 4,0 $\pm$ 1,0 days (p < 0,01) and 14,5 $\pm$ 0,9 versus 6,5 $\pm$ 1,1 (p < 0,01)). In addition to this, open curettage was found to have more complications than minimal invasive curettage (1 patients with sural neuritis, 1 patient with CPC leakage. The difference in complications was not statistically significant with p value = 0,131.[4]

From all of the above explanations, we can conclude that majority of both clinical and radiological outcomes favors the use of minimal invasive curettage as compared to open curettage.

CONCLUSION

Three studies were included in this systematic review. Among those three studies, eleven outcomes involving both clinical and radiological outcomes were assessed to compare between open and minimal invasive curettage. Majority of the study outcomes reported that minimal invasive curettage was superior to open curettage. From two studies, it was found that minimal invasive curettage was superior as evaluated by Chang's radiological evaluation. In addition to this, evaluated from all of the included studies, minimal invasive curettage was superior when evaluated from AOFAS ankle/hindfoot scale, time to complete radiological healing, and number of complications. Even, statistical significant difference favoring minimal invasive curettage was found in mean hospital stay, time to full weight bearing, time to return to sport activities, and time to solid union. However, mean operating time result comparing open and minimal invasive curettage was inconsistent, because one study favors the use of open curettage while the other favors the use of minimal invasive curettage. Besides, mean number of procedure and recurrence were relatively the same between open and minimal invasive procedure. In conclusion, we recommend the use of minimal invasive curettage to treat simple bone cyst. However, further study with higher amount of included studies and sample size is needed in order to conclude better conclusion regarding this topic.

Declaration by Authors

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