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Impact of avascular necrosis on outcomes in the management of developmental dysplasia of hip: a systematic review

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Avascular necrosis (AVN) is a known complication during the management of developmental dysplasia of the hip (DDH). It has the potential to alter the growth of the head or acetabulum and prevent the best outcomes. While past literature has evaluated the risks of AVN and strategies to avoid it, studies on the impact of AVN on the outcomes are scarce. In this systematic review, we aim to study the extent of the effects of AVN on the outcomes, in the management of DDH. In this systematic review series for 1990 to 2021 were pooled. The clinical and radiological outcomes of the AVN and non-AVN groups were compared. The effects of other modifying factors were also evaluated. A total of 170 AVN and 585 non-AVN hips from 21 papers were compared. The analysis did not show any statistically significant difference between the AVN and non-AVN groups in terms of clinical or radiological parameters. Interestingly patients who had the index surgery at a younger age had a higher risk of further surgery, with acetabular osteotomy being the most common secondary procedure. The negative impact of AVN may not be as severe as previously thought. Thus, the fear of AVN should not take precedence over the primary goal of DDH management i.e. obtaining a stable concentric mobile hip.

Keywords: Developmental dysplasia of hip, avascular necrosis

INTRODUCTION

The ultimate goal of the treatment of developmental dysplasia of the hip (DDH) is to obtain a concentric reduction so that the head and acetabulum can develop together[1-4]. Complications of surgery in DDH include infection, avascular necrosis (AVN), coxa vara/valga/magna, trochanteric overgrowth, residual acetabular dysplasia, subluxation, dislocation and joint degeneration[5]. AVN is always considered the major impediment to achieving the best outcomes in DDH, as it can cause asphericity or irregularities of the head and can alter the neck-shaft angle[5-8]. This can result in abnormal gait, limb length discrepancy, degeneration and pain[3,5]. Multiple previous studies have solely focused on the evaluation and prevention of the risk factors for AVN. This overwhelming consideration of AVN has also resulted in various changes in the protocols of DDH management[2,5,9-13].

However, despite considering AVN as the most dreaded complication of DDH management, there are only a handful of studies which have evaluated the real impact of AVN on the outcome[6,14-17]. Evaluating the effect of AVN on the outcomes is difficult, as it is neither desirable nor can be allowed to run its natural course on ethical grounds. Also, the smaller number of AVN in the series makes the creation of the cohorts difficult. Thus in this systematic review, we attempt to combine cases from all the previous literature and study the extent of the impact of AVN on the outcome in DDH management.

MATERIAL AND METHODS

A detailed literature search was done in PUBMED, MEDLINE, and EMBASE using the bullion search "DDH treatment", "surgery in DDH", and "AVN in DDH". Articles were downloaded and their references were also searched. Of these, only full-text articles published in English between 1990 and 2020 regarding surgical management were further evaluated for the study. Only those articles which had the detailed master chart of the treatment, have clearly mentioned the AVN status and outcome (at least in terms of Severin or McKay grades) were included in the study[18,19]. Studies where the treatment was only closed reduction and hip spica with or without adductor tenotomy or in those the AVN status for each case was not mentioned or in those Severin/McKay grades were not mentioned in the outcome status were excluded. Case reports or publications in unsolicited journals were also excluded.

Detailed information from each article was then extracted and compiled regarding demographic data, surgical procedure, follow-up, and final outcomes. The preoperative information included age at initial surgery, sex, Tonnis grade, side of involvement, presence or absence of ossific nucleus, preoperative acetabular index (AI), and centre edge angle (CEA). In the cases where multiple surgeries were done the first open reduction was considered the index procedure. Multiple surgical procedures were described. But for ease of evaluation, they were broadly grouped as medial open reduction (MOR), anterior open reduction (AOR), femoral shortening with varus (VDO) or without varus (FO), concentric acetabular osteotomy (AO Con – Dega, Pemberton, San Diego, Salter), nonconcentric acetabular osteotomy (AO NC – Chiari, Shelf) and their combinations[6]. The final outcomes included were Severin and McKay grades, the latest AI and CEA, and the need for further surgery. Long-term outcomes like Harris hip score, Iowa hips score, WOMAC hip score, and joint degeneration (Boyers grade) were also evaluated when available[20]. Details of AVN status included the presence or absence of AVN. When available, grades of AVN were also included. AVN grades were mentioned in the Bucholz-Ogden grade or Kalamchi MacEwan classification[21,22]. However, considering the similarities in these classifications they were assigned similar values.

Patients were then classified into 2 groups, those who had AVN during the treatment and those who had no radiological signs of AVN during the course of treatment (NAVN), and these groups were compared. A comparison of parametric data was done with the unpaired two-tailed t-test. Significant differences in the nonparametric data were tested with either the Chi-square test or Man Whitney U test whichever was better suited. Multivariate analysis was done to evaluate the effect of independent variables other than AVN (age, sex, side, Tönnis grade, presence or absence of ossific nucleus at the time of surgery, initial surgical procedure, follow-up duration, preoperative AI, and CEA) on the outcomes measures (Severin and McKay grades, AI and CEA at the final follow up and need of further surgery) by calculating the beta coefficient and p-value. Statistical analysis was done by using Microsoft Excel, SPSS, and an online calculator.

Previous literature has noted that the full scale of the effects of AVN, especially the Kalamchi type II ones takes 8-12 years to appear. The delayed appearance of the AVN results in a change in the neck-epiphysis angle and late deterioration of the CEA[15,23-25]. So a shorter follow-up may underestimate the AVN incidence and the full extent of the effect of AVN on DDH management. Thus another comparison was done among the AVN and NAVN groups comprising only those with >10 years of follow-up.

It has also been noted previously that all AVN can't be grouped together and the classification of AVN should rather be binary mild variety (type I and II) and severe variety (type III and IV). These two varieties differ in terms of the severity of involvement and in turn the prognosis[16,25]. So these mild and severe groups were also compared to each other for statistically significant differences.

RESULTS

A total of 758 articles were searched, of which 185 full texts were reviewed and 22 were selected for the study. Two of these were from the same author in quick succession, so the initial publication was excluded[10,26]. These 21 articles together have reported 170 hips with AVN and 585 hips without AVN[1,2,6-8,11,12,14,15,23,24,26-35]. The demographic data in both of the groups were similar (table 1). Only the follow-up duration was higher in the NAVN hips as compared to AVN hips. While AVN hips had primarily Severin II/III outcomes, it was mostly I/II in NAVN hips. Similarly, McKay's score was mostly good/fair in AVN but excellent/good in NAVN, and Boyer's degeneration was mostly I/II for AVN and 0/I for NAVN. AVN hips also needed a higher proportion of secondary surgeries as compared to NAVN hips (figure 1). However, on further analysis, the differences between the AVN and NAVN hips in terms of McKay and Severin grades, degeneration grades, final CEA, WOMAC, Iowa hip score, or need for further surgery are not statistically significant (table I). Only the AI and Harris hip scores showed a statistically significant difference. The mean AI angle was 23.4° and 20.6° degrees respectively for the AVN and NAVN hips.

For hips with more than 10 years of follow-up after index surgery, 66 developed AVN, and 198 had no AVN. The demographic distribution between AVN and NAVN groups was comparable. Hips that had AVN were at a significantly higher risk of further secondary

Table I. — Comparison of AVN Vs No AVN groups

	AVN (n)	Distribution	NAVN (n)	Distribution	Test used	p
Procedure	170	MOR – 56 AOR – 8 CR+AO Conc – 2 OR+AO Conc – 40 OR+AO NC – 1 OR+FO- 0 OR+VDO – 20 OR+AO Conc+FO – 16 OR+AO NC+FO – 2 OR+AO Conc+VDO – 21 OR+AO NC+VDO – 4	585	MOR – 190 AOR – 45 CR+AO Conc – 30 OR+AO Conc – 80 OR+AO NC - 0 OR+FO – 1 OR+VDO – 22 OR+AO Conc+FO – 126 OR+AO NC+FO – 11 OR+AO Conc+VDO – 70 OR+AO NC+VDO – 10	MUT	0.10
McKay	56	Excellent 14 Good – 20 Fair - 19 Poor - 3	255	Excellent 128 Good – 94 Fair – 25 Poor – 8	MUT	0.20
Severin	168	I-24 II-75 III-46 IV-18 V-2 VI-3	578	I – 314 II – 167 III – 62 IV – 26 V – 3 VI – 6	MUT	0.34
Degeneration	32	0 -6 I –11 II – 12 III - 3	91	0 – 51 I –29 II – 11 III – 0	MUT	0.56
Further Surgery	170	33/137	585	68/517	X^2 OR	0.061.85
AI Final	72	23.4±10.4	305	20.6±8.5	T test	0.02
CEA Final	71	26±14.6	350	28.9±12.2	T test	0.08
Harris hip score	2	81±0.1	31	95.6±8.6	T test	0.02
WOMAC hip score	2	23.3±8	29	7.7±14.2	T test	0.14
IOWA hip score	30	91.1±5.6	62	93.2±6.1	T test	0.14

Abbreviations: MOR – medial open reduction, AOR – anterior open reduction, CR – closed reduction, AO Conc – acetabular osteotomy for concentric reduction (Salter, Dega, Pemberton), AO NC – acetabular osteotomy for non-concentric reduction (Chiari, Shelf), FO- femoral shortening osteotomy, VDO – varus derotation osteotomy, T test – unpaired 2 tailed t test, MUT - Man Whitney U test, X^2 – chi square test, OR – odds ratio.

surgeries (28.8%) as compared to those without AVN (17.1%). For all other outcome measures, there was no statistically significant difference between the AVN and NAVN groups.

The multivariate analysis showed that only three of the independent variables, age at index surgery, Tonnis grade, and preoperative AI have a statistically significant effect on the outcome measures (table II). The age at index surgery has contrasting effects on the AI and CEA. Higher age at index surgery tends to reduce AI, (0.453° for an increase of each month of age) thus having a better outcome. But it also tends to reduce the final CEA (0.887° CEA for each month of age) which is not desirable. As expected, a higher Tönnis grade results in poorer outcomes as seen with higher McKay, and Severin scores and the need for secondary surgeries. Higher Tönnis grade also raises the final AI and CEA, the increase is 0.6-0.7° per increase of Tönnis grade, which may not be clinically significant. Preoperative AI also tends to increase the final AI by 20%.

A comparison of the AVN and NAVN hips with more than 10 years of follow-up following the index surgery also showed similar results (figure 2). Their demographic distribution except for follow-up duration showed no statistically significant difference. The outcome measures (Severin, McKay, Boyer's grades, IOWA hip score, final AI, and CEA) were also similar except that the AVN hips needed significantly more secondary surgeries. The comparison of mild AVN (Kalamchi type I and II) and severe AVN (type III and IV) showed similar demographic distribution.

Table II. — Effect of independent variables (other than AVN status) on the outcome as per the multivariable analysis

Independent variable	Outcome being affected	Beta estimate (extent of effect)	p-value	Clinical significance
Age at Sx	AI final	-0.453	0.053	Yes
	CEA final	-0.887	0.02	Yes
	Need of further Sx	-0.521	0.018	Yes
Tonnins	McKay score	0.355	0.034	Yes
	Severin score	0.326	0.057	Yes
	AI final	0.597	0.000	May be
	CEA final	0.757	0.000	May be
	Need of further Sx	0.575	0.001	Yes
AI Preop	AI final	0.215	0.019	Yes
	CEA final	0.084	0.000	No
	Need of further Sx	0.04	0.025	no
Abbreviations: Sx – surgery, AI – acetabular index, CEA – centre wedge angle.				

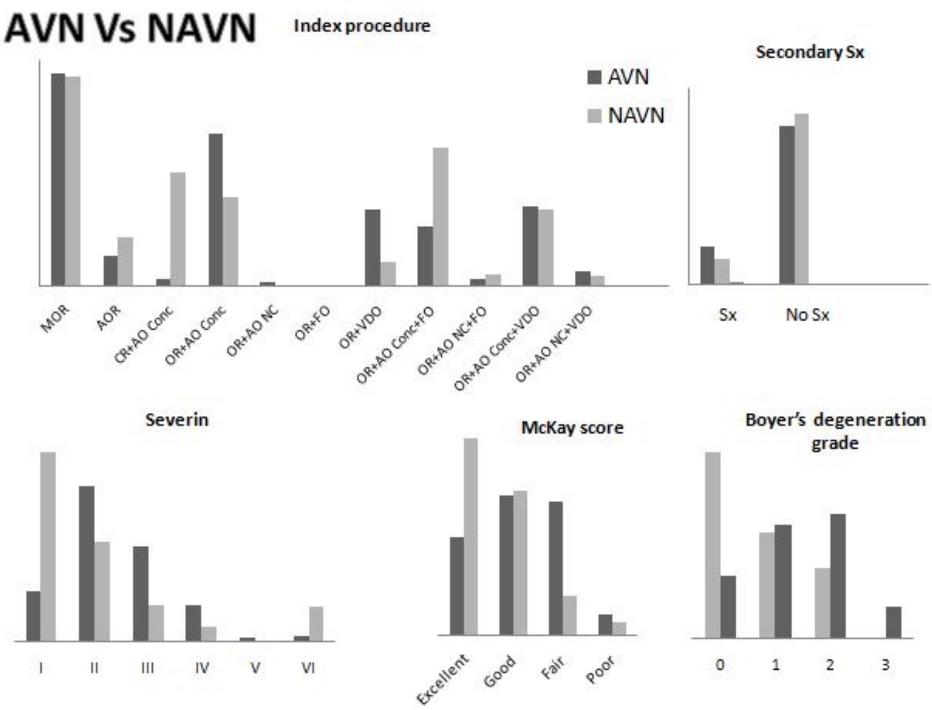

Figure 1 — Comparison between AVN and NAVN groups.

However, the hips that had severe AVN had a higher age at index surgery, which would explain the difficulty in reduction resulting in AVN. The outcome measures, except the Iowa hip score, showed no statistically significant difference in mild and severe hips (figure 3). Iowa hip score was significantly higher among the mild AVN hips, implying they had better outcomes, which is understandable. Though not statistically significant, interestingly the secondary surgery rates were higher in the mild AVN group as compared to the severe AVN group. Presently there is no explanation to explain this strange phenomenon, and this needs further studies.

DISCUSSION

Avascular necrosis is considered the most dreaded complication possible during the management of DDH. It has the potential to produce various patho-morphological changes in the proximal femur, and the loss of the head acetabular congruity places eccentric

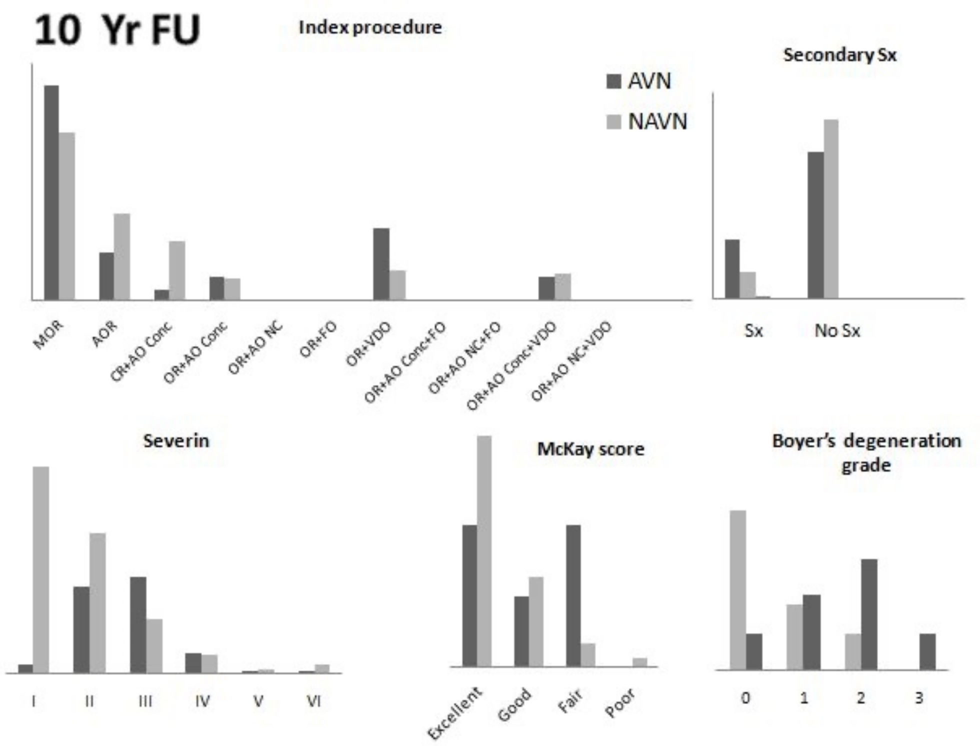

Figure 2 — Comparison between AVN and NAVN hips with more than 10 years follow up.

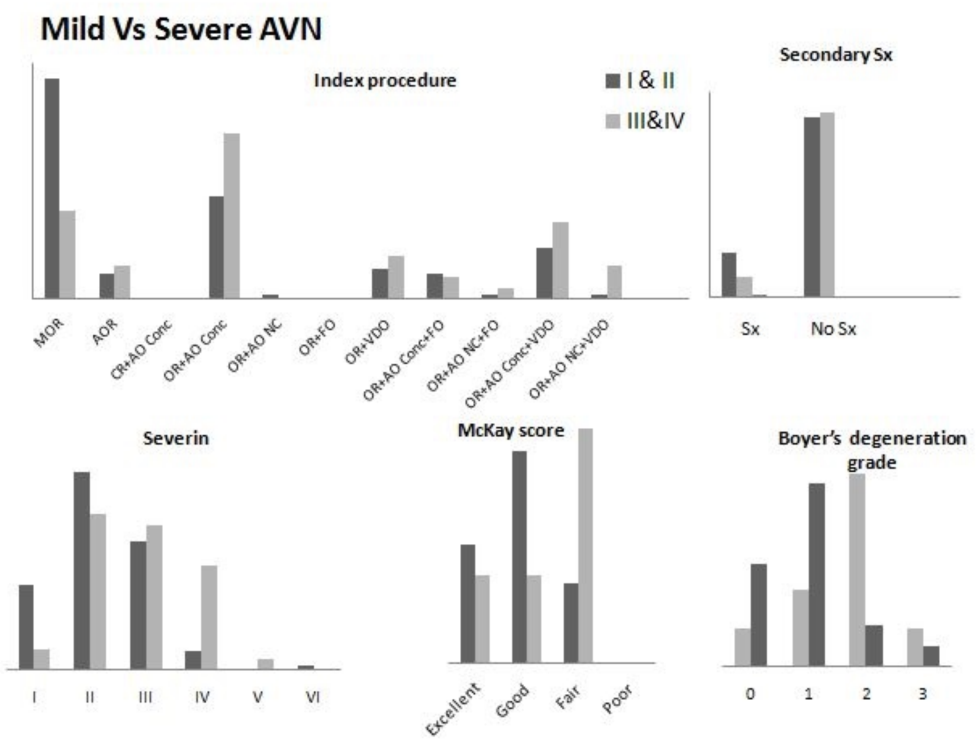

Figure 3 — Comparison between hips with mild AVN (grade I/II) and severe AVN (grade III/IV).

pressure on rapidly growing impressionable cartilage resulting in adaptive deformities on both sides[3,17]. However it is unclear whether these changes are clinically relevant[16].

Previous studies have seen a significant rate of AVN among those who had unsatisfactory outcomes[8,9,24]. Significant downgrading of the radiological and clinical parameters in the long term was also noted due to the development of type II AVN[13,23,24]. Kothari et al in a meta-analysis have noted AVN hips have a 34 times higher risk of developing Severin III or higher grades of outcomes as compared those without AVN[4]. However the impact of AVN on clinical parameters like McKay score was much less severe[23,25]. Weinstein and Deyo have suggested that there are 4 aspects of outcome assessment: patient well-being or health status, cost, expectation, and clinical & radiological status. These traditional orthopaedic outcomes assess only the clinical & radiological parameters[36]. Roposch et al evaluated health-related outcomes after DDH surgery in long term and found that AVN results in loss of hip-specific functions like the range of motion, contracture and stiffness, but the activity score and health-related quality of life did not change much[16]. Cicekil noted that even though the frequency of AVN was higher in patients with IOWA hip scores < 90, there was no correlation between AVN and IOWA hip scores. Thus there may not be any direct correlation between AVN and IOWA hip score[6]. Few previous studies also have noted that even though rates of unsatisfactory outcomes were higher in AVN hips, the difference was not statistically significant at long-term follow-up[2,6,14]. AVN rates increase in the long term, due to late-appearing type II AVN. This results in a late downgrading of the Severin score but the McKay score mostly remains unchanged[15,23-25]. AVN also doesn't increase the risk of further surgery, as more than 50% of additional surgeries in AVN are for residual dysplasia rather than for AVN. Thus AVN related proximal femoral deformities do not necessarily mean poor acetabular development and good outcomes can be seen in the majority of AVN hips[15,36-38].

This study is the largest systematic review, evaluating the clinic-radiological outcomes of the AVN after DDH surgery in comparison to those who did not have AVN. In contrast to most of the previous literature, in this study, we did not find any significant difference between the AVN and NAVN groups in terms of radiological (CEA, AI, Severin grade, Boyer's degeneration grade) and clinical (McKay grade, IOWA hip score, need of further/secondary surgeries) parameters. Only final AI and Harris hip scores were significantly different among the AVN and NAVN groups. Though statistically significant, the clinical importance of such difference will be minimal as this can arise from minor variations in the measurements, and both 23.4° and 20.6° are within the acceptable range of AI. Similarly, though Harris hip score was significantly lower in the AVN hips, as there were only 2 AVN hips where Harris hip scores were measured, it is difficult to comment on such data.

Also in the present study, there was no significant difference neither between the outcomes of AVN and NAVN groups at 10 years of follow-up nor between the mild and severe types of AVNs. The less-than-expected effect of AVN may be because a typical sequel of AVN i.e. condensation-fragmentation-repair is absent in AVN related to DDH treatment. This is also supported by the fact that the average CHOHES hip score in DDH-related AVN was 85, which is far better than 75 for sickle cell anaemia and 60 for Perthes'[16,17].

Considering AVN prevention is one of the primary goals of DDH treatment, concluding that 'AVN does not significantly change the outcomes of DDH surgery' will have many important implications on the planning and management of DDH treatment. Past literature has proposed multiple protocols solely to prevent AVN like waiting for the ossific nucleus to appear, avoiding open reduction in infancy, avoiding acetabular osteotomy, avoiding femoral varus osteotomy, or a higher degree of abduction during hip spica[10,11,13,30,34]. However, avoiding acetabular or femoral varus osteotomy or reducing the abduction during spica may sometimes compromise the stability of reduction and is at odds with the most important aim of DDH treatment i.e. to have a stable and concentric reduction. This is especially important in older children, who have a flattened head and dysplastic acetabulum[12,31]. Oshako et al had proposed that acetabular dysplasia resolves spontaneously if an open reduction is done before 2 years of age[34]. But others have noted that in comparison to the femoral head, acetabular dysplasia is less likely to resolve spontaneously and the acetabular osteotomy is the most common secondary surgery in hips that underwent isolated open reduction[12,37]. In the present study, the multivariate analysis showed that with increasing age at index surgery, the need for further surgery and final AI decreases. This is in contradiction to common knowledge. We think that this may be because acetabular osteotomy is the most common secondary surgery in DDH in patients who underwent index procedures at a younger age, but for older children was combined with the index procedure. We also noted that among the hips which needed further surgery, isolated acetabular osteotomy was the most common procedure (70% in AVN and 77% NAVN hips). In contrast, isolated proximal femoral osteotomy was needed in only 9% of AVN and 11% of NAVN hips. Secondary surgeries are very important from the patient's perspective adding much cost and inconvenience[23]. Thus we reiterate previous observations that supplementary acetabular osteotomy or varus osteotomy should be done at index surgery when indicated, as the first operation is the golden chance to give better results, favourable outcomes, and fewer complications[12,30].

The present review showed that in contrast to most previous studies, AVN doesn't significantly change the final outcomes. However, before drawing these conclusions we should also consider a few of the facts. First of all, there is no universally accepted classification system for AVN[17,18,21,22,40]. Salter et al. stated that coxa magna is a sign of AVN[40]. But later studies have noted that mere hypertrophy without any loss of height is the result of hypervascularity and should not be categorized as AVN. As the prevalence of coxa magna can be 48-88%, this disagreement in definition could have resulted in the discrepancy in the outcome of the present study and previous literature[2,12,16,39]. Secondly type II AVN is one of the important causes of late downgrading of outcomes. Approximately 2/3 of the hips in the present review had follow-up <10 years, which may underestimate the prevalence and effect of AVN. Finally, the hips in this review have huge diversity in terms of age, Tönnis grade, and surgical methods. Also, none of the series has evaluated all of the outcome parameters leaving some outcomes like Harris hip score, and WOMAC hip score with very few hips. This diversity and inadequacy make interpretations less definitive. Considering these we suggest that future prospective multicentre long-term studies are performed, to study the effect of AVN on the outcomes during DDH management.

CONCLUSION

Avascular necrosis of the femoral head following DDH surgery has been considered one of the major causes of poor outcomes. But according to the review these negative effects of AVN especially on the clinical parameters, may not be as severe as previously thought. Fear of AVN should not compromise the additional surgical procedures for the stability of reduction, which always remains the primary aim of any DDH treatment.

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