

# Greater Trochanter Apophysiodesis in Legg–Calve–Perthes Disease: Which Implant to Choose?

## Abstract

**Background:** Greater trochanter apophysiodesis (GTA) is relatively minimal invasive technique for the treatment of trochanteric overgrowth. Various types of implants can be used in each procedure. The purpose of this study was to compare outcomes of three different types of implants that were used in treatment of trochanteric overgrowth in Legg–Calve–Perthes disease. **Materials and Methods:** We retrospectively studied radiological results of three implants (screw, screw washer, and EP) on inhibiting trochanteric growth in 32 patients. Articulo-trochanteric and trochanter-trochanter distances (TTDs) were measured on radiographs. Embedding of implant evaluated on final radiographs. **Results:** The mean of age at the surgery was  $10 \pm 2.3$  years, and the mean of follow up period was  $50.0 \pm 16.7$  months. In all groups, articulo-trochanteric distance was decreased on final radiographs. In screw and screw washer group, increase of TTD was not statistically significant ( $P < 0.05$ ). Twelve, one, and two implants were embedded, respectively, in screw, screw washer, and EP groups. Two patients in EP group had revision surgery due to loosening. **Conclusions:** In this study group, GTA using screw and screw washer methods could slow down but did not restore trochanteric overgrowth. We suggest using washer to reduce embedding of the screw.

**Keywords:** Apophysiodesis, epiphysiodesis, growth modulation, Legg–Calve–Perthes, trochanteric overgrowth

## Introduction

In Legg–Calve–Perthes disease (LCPD), proximal femoral epiphysis is primarily affected region and slowing of the femoral head-and-neck growth is common.<sup>1,2</sup> Because of having a separate extracapsular blood supply, unaffected greater trochanter (GT) continues to grow and leads to a relative overgrowth according to femoral head and neck.<sup>3</sup> This relative overgrowth weakens the abductor muscles of the hip and can cause extra articular impingement between the GT and the ilium.<sup>4-6</sup>

Distal and lateral advancement of the GT or lengthening of the femoral neck procedures can be used to treat relative overgrowth of GT.<sup>5-7</sup> These surgeries showed improvements in gait and relief of pain.<sup>4,7</sup> In skeletally immature patients, physal arrest can be another option. In certain age group, it has been showed that, GT apophysiodesis (GTA) might prevent relative overgrowth of GT, and

it is relatively less invasive procedure than other surgical treatment options.<sup>4,6,8-10</sup> However, there is little consensus regarding the effectiveness, timing, and technique of GTA.<sup>2,3,11</sup> Different techniques have been described for inhibiting the GT growth. In GTA procedure, screw (S), screw and washer (SW), and eight-plate (EP) are commonly used implants for growth modulation.<sup>7,10-12</sup> However, it is unclear that which implant configuration is more superior in slowing down the growth of GT.

In this study, we aimed to evaluate the radiological outcomes of widely used implants for the treatment of GT overgrowth in LCPD. We retrospectively reviewed patients, who had GTA with three implant configurations: S, SW, and EP. All implants have successful outcomes and shown that have impact on growth modulation. Therefore, we hypothesized that all implant configurations will show similar improvements on radiographic parameters in treatment of relative overgrowth of GT in LCPD.<sup>7,11,13</sup> To the best of our knowledge, this is the first study

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### Access this article online

**Website:** www.ijoonline.com

**DOI:**  
10.4103/ortho.IJOrtho\_166\_18

### Quick Response Code:



**How to cite this article:** Akpınar E, Ozyalvac ON, Bayhan IA, Beng K, Kocabiyik A, Yagmurlu MF. Greater trochanter apophysiodesis in Legg–Calve–Perthes disease: Which implant to choose?. Indian J Orthop 2019;53:548-53.

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that compares the radiological outcomes of S, SW, and EP in GTA procedure.

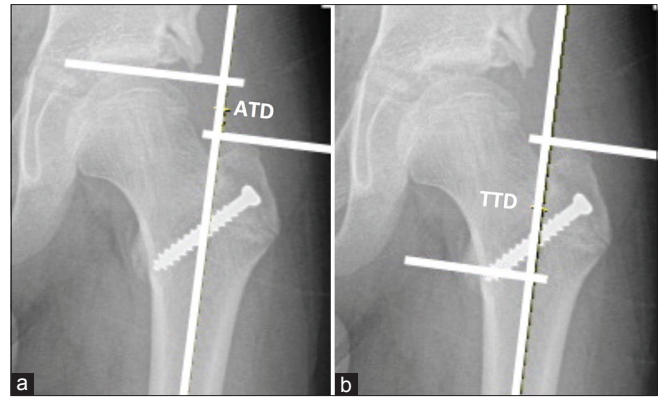
## Materials and Methods

After approval from the Institutional Review Board, a retrospective review of operative logs from October 2008 to December 2014 was undertaken to identify all LCPD who underwent GTA. All GTA surgeries were performed using minimal invasive method as in guided growth technique, by applying implants *in situ* without performing curettage or drilling of the GT growth plate. Patients, whom only GTA was performed, allowed weight bearing as tolerated with two canes for 1 or 2 weeks. Then patients allowed walking without canes after pain resolved. Patients, whom femoral or pelvic osteotomies were performed, restricted weight bearing. After 4 or 6 weeks postoperatively, allowed weight bearing as tolerated with two canes for 3 or 4 weeks. Medical records were reviewed to document the followings: age at surgery, gender, followup period, previous or simultaneous surgeries, and complications related to the surgery.

Fifty-two patients with LCPD that had GTA were collected. From them, patients that had bilateral LCPD, patients who did not have appropriate radiographs, and patients with <1-year followup after surgery were excluded from the study.

Radiographic parameters were evaluated on initial and final anteroposterior pelvic radiographs, which were obtained in hips in extension and neutral rotation. Articulo-trochanteric distance (ATD) and trochanter-trochanter distance (TTD) measurements were made using the ruler tool on INFINITT Health care Picture Archiving Communication System (INFINITT Health care Co., Ltd., Seoul, South Korea). Two observers (EA, ONO) evaluated the radiographs. Each observer reviewed the radiographs twice with 1-week interval to determine the intraobserver reliability over time. Both observers were blinded to their previous measurements and measurements recorded by the other observer. The interclass correlation coefficient (ICC) values at 95% confidence intervals (CIs) were estimated for the interobserver and intraobserver reliability.

Height of GT was evaluated by measuring ATD and TTD. ATD was defined as the distance from the superior portion of the femoral head to the tip of the GT along the anatomical axis of the femur [Figure 1a].<sup>11,14</sup> When the superior portion of the femoral head stayed below to the tip of the GT, it was referred as a “negative” value. TTD was defined as the distance from the tip of the GT to the middle of the lesser trochanter along the anatomical axis of the femur [Figure 1b].<sup>11,14</sup> ATD and TTD were measured on both treated and contralateral hips of the patients and the difference between both sides was referred as  $\Delta$ ATD ( $\Delta$ ATD = ATD contralateral-ATD treated) and  $\Delta$ TTD ( $\Delta$ TTD = TTD contralateral-TTD treated). The difference of  $\Delta$ ATD and  $\Delta$ TTD between initial and final radiographs was used to evaluate the outcome of the



**Figure 1: Measurements made on anteroposterior radiographs to evaluate effectiveness of greater trochanter apophysiodesis. (a) Articulo-trochanteric distance. (b) Trochanter-trochanter distance**

surgery in each implant. The magnitude of change of the  $\Delta$ ATD and  $\Delta$ TTD values on initial and final radiographs was referred as  $\Delta$ ATDD ( $\Delta$ ATD differences) and  $\Delta$ TTDD ( $\Delta$ TTD differences), which was used to compare the outcomes of surgery between implants.

Positions of implant in GT were compared between final and initial radiographs. The term “embedding” was used for an implant that the screw head, which was not covered by bone on immediate postoperative radiographs, has the appearance of the screw head surrounded by bone and becomes buried on final radiographs. Embedded implants were noted in each group.

Normal distribution of data was evaluated with skewness and kurtosis. Kruskal–Wallis test was used to compare the age and followup periods between the groups. The Wilcoxon signed-rank test was used to compare  $\Delta$ ATD and  $\Delta$ TTD data preoperatively and postoperatively. Mann–Whitney U-test was used to compare  $\Delta$ ATDD and  $\Delta$ TTDD data between implant groups. A value of  $P < 0.05$  was considered statistically significant and all statistical analysis was performed using IBM SPSS Statistics for Macintosh, version 20.0 (Armonk, NY, USA).

## Results

From 52 patients, a total of 32 patients met to the inclusion criteria, 5 (16%) females and 27 (84%) males. The mean of age of at the surgery was  $10 \pm 2.3$  years, and followup period was  $50.0 \pm 16.7$  months. GTA performed using S, SW, and EP in 13, 10, and 9 patients, respectively. Seven (54%) patients in S, five (50%) patients in SW, and two (22%) patients in EP had previous pelvic or femoral osteotomy. At the time of GTA, seven (54%) patients in S, one (10%) patient in SW, and two (22%) patients in EP had simultaneous pelvic or femoral osteotomy [Table 1]. Between S, SW, and EP, the mean of age and the mean of followup time did not show statistically significant difference [Tables 2 and 3].

For radiographic measurements, intraobserver reliability was excellent for the ATD (ICC = 0.99,

**Table 1: History of previous or simultaneous surgery**

Surgery	S		SW		EP	
	Prev	Sim	Prev	Sim	Prev	Sim
Triple Shelf	2	7	2	1	1	2
Salter			2			
Valgus	2		1			
Varus	1					

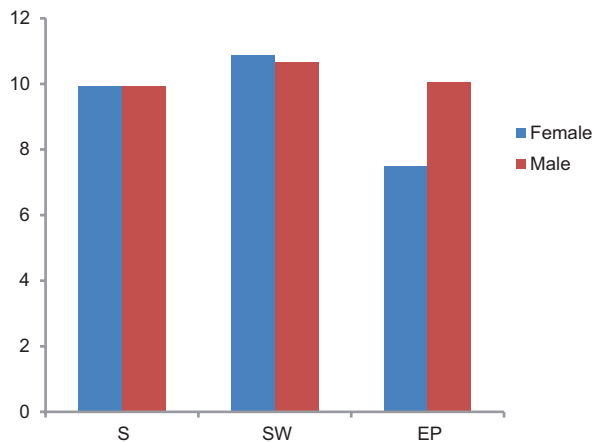
S=Screw, SW=Screw and washer, EP=Eight-plate, Prev=Previous surgery, Sim=Simultaneous surgery, Triple=Tönnis triple osteotomy, Shelf=Staheli shelf procedure, Salter=Salter innominate osteotomy, Valgus=Femoral valgus osteotomy, Varus=Femoral varus osteotomy

**Table 2: Demographic data of patients**

Groups	Patients (n)	Gender		Mean±SD	
		Female	Male	Age at surgery (years)	Follow up (month)
S	13	2	11	9.9±2.1	56.0±16.0
SW	10	1	9	10.7±1.9	47.2±18.0
EP	9	2	7	9.5±2.9	44.5±15.1
Total	32	5	27	10.0±2.3	50.0±16.7
P*				0.515	0.241

\*Kruskal-Wallis test. SD=Standard deviation, S=Screw, SW=Screw and washer, EP=Eight-plate

**Table 3: Distribution of mean ages according to gender definition of values (years)**



S=Screw, SW=Screw and washer, EP=Eight-plate

95% CI = 0.98–0.99) and TTD (ICC = 0.95, 95% CI = 0.90–0.98). Furthermore, interobserver reliability was excellent for the ATD (ICC = 0.96, 95% CI = 0.87–0.99) and the TTD (ICC = 0.97, 95% CI = 0.94–0.98).

At the final followup, ΔATD was increased in all groups; however, the difference was only statistically significant in SW. Furthermore, ΔTTD was increased in S and SW, which the differences were statistically significant [Tables 4-7].

Since the ΔTTD improvement was statistically significant on S and SW, further analysis was done to compare the

magnitude of change in ΔATD and ΔTTD between the groups. The differences of ΔATDD and ΔTTDD between S and SW were not statistically significant [Tables 8 and 9].

On final radiographs, bone coverage on implants was observed in two forms. Embedded screw heads in S and SW were fully covered with bone; however, only the proximal part of the EP was covered with the bone in EP [Figure 2]. Twelve (92%) implants in S, one (10%) implant in SW, and two (22%) implants in EP were embedded in bone on final radiograph.

Two patients in EP had revision surgery due to loosening of implants after 2 and 8 months of initial surgery. S was applied for the first patient; EP was reapplied for the second patient.

## Discussion

In LCPD, GTA has been recommended when relative overgrowth of GT is a concern.<sup>7,10,11,13</sup> Various techniques have been described for inhibiting the GT growth in the literature such as Plemister technique, applying screw with curettage and drilling of the growth plate or applying EP without drilling of the growth plate as a guided growth technique.<sup>7,10-12</sup> It is unclear that to state the best time to perform GTA and which method is more effective in slowing down the growth of the GT.<sup>2,3,11</sup> To the best of our knowledge, this is the first study that compares the radiological outcomes of S, SW, and EP in GTA. Screw is commonly used implant in GTA. We believed that applying screw with washer may be more effective in terms of slowing GT growth, but we did not meet any study that compares effectiveness of adding washer beside screw GTA.

The ultimate shape of the proximal end of the femur is determined by the growth velocities of the femoral head and GT (14). In LCPD, the growth arrest of the femoral head can cause relative overgrowth of GT that decreases ATD.<sup>10</sup> Most authors used ATD to determine level difference between femoral head-GT and to report outcomes of studies.<sup>11</sup> In this study, our aim was to evaluate slowing effect of implants on GT growth, not evaluate the results in terms of restoring trochanteric height. We had the chance to compare trochanteric growth in older patients, which still continues up to maturity. In this study, ΔATD were used to determine restoration of normal femoral head levels in patients treated by the GTA methods. We observed that ATD worsened in all groups, especially in SW on final radiographs. We believe that the amount of flattening of femoral which was not compensated by GTA lead ATD worsening. Regardless of method, GTA did not restore normal femoral head level in the treatment of relative overgrowth of GT. We observed similar outcomes as in the literature as a result of this study group's relatively high mean age.

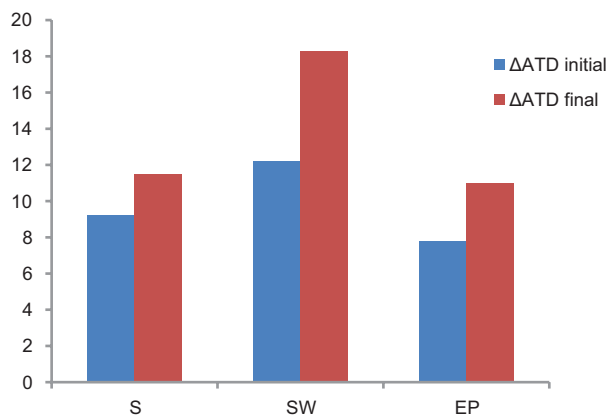
ATD is an indirect measure of the GT growth and also reflects the growth of the femoral head.<sup>11</sup> Therefore, changes of ATD affected by both trochanteric growth and flattening of the femoral head in the progression of disease.

**Table 4: Articulo-trochanteric distance contralateral–Articulo-trochanteric distance treated data of initial and final radiographs**

Groups	ΔATD initial (mm)		ΔATD final (mm)		P*
	Mean±SD	Median	Mean±SD	Median	
S	9.2±6.4	9.4	11.5±8.7	14.1	0.116
SW	12.2±4.4	13.6	18.3±9.6	18.1	0.028
EP	7.8±5.6	7.9	11.0±10.0	12.5	0.260

\*Wilcoxon signed ranks test. SD=Standard deviation, S=Screw, SW=Screw and washer, EP=Eight-plate, ATD=Articulo-trochanteric distance, ΔATD=ATD contralateral–ATD treated

**Table 5: Mean values of Articulo-trochanteric distance contralateral–Articulo-trochanteric distance treated data of initial and final radiographs (mm)**



S=Screw, SW=Screw and washer, EP=Eight-plate, ATD=Articulo-trochanteric distance, ΔATD=ATD contralateral–ATD treated

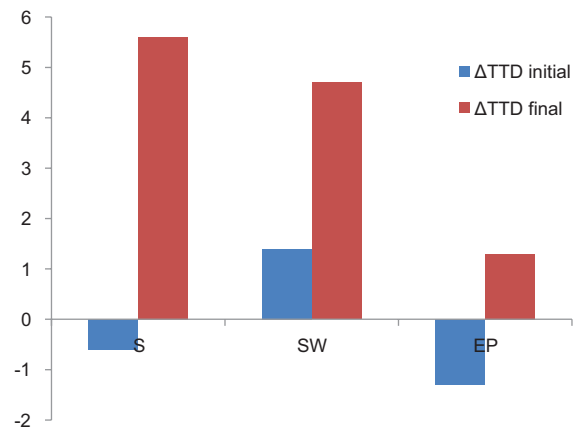
**Table 6: Trochanter-trochanter distance contralateral–Trochanter-trochanter distance treated data of initial and final radiographs**

Groups	ΔTTD initial (mm)		ΔTTD final (mm)		P*
	Mean±SD	Median	Mean±SD	Median	
S	-0.6±3.9	-0.6	5.6±4.9	4.8	0.003
SW	1.4±4.0	0.9	4.7±6.5	4.5	0.028
EP	-1.3±3.4	-2.5	1.3±3.5	2.3	0.214

\*Wilcoxon signed ranks test. SD=Standard deviation, S=Screw, SW=Screw and washer, EP=Eight-plate, TTD=Trochanter-trochanter distance, ΔTTD=TTD contralateral–TTD treated

The variability of the amount of femoral head flattening may lead difficulties in evaluating trochanteric growth. However, TTD directly represents GT growth and does not affect by growth of femoral head.<sup>11</sup> While GTA alters the TTD, ΔTTD can be used to measure the amount of benefit derived from the procedure.<sup>14</sup> In this study, ΔTTD was increased in all groups, especially in S and SW, which were statistically significant. Therefore, S and SW seem to have more effectiveness on inhibiting the growth of GT than EP. Despite any benefit in terms of restoring normal ATD

**Table 7: Mean values of Trochanter-trochanter distance contralateral–Trochanter-trochanter distance treated data of initial and final radiographs (mm)**



S=Screw, SW=Screw and washer, EP=Eight-plate, TTD=Trochanter-trochanter distance, ΔTTD=TTD contralateral–TTD treated

**Table 8: Articulo-trochanteric distance contralateral–Articulo-trochanteric distance treated difference and Trochanter-trochanter distance contralateral–Trochanter-trochanter distance treated difference data of screw and screw and washer groups**

Groups	ΔATDD (mm)		ΔTTDD (mm)	
	Mean±SD	Median	Mean±SD	Median
S	2.3±5.9	2.8	6.2±5.0	5.4
SW	6.1±8.8	4.4	3.2±4.3	1.9
P*	0.343		0.148	

\*Mann–Whitney U-Test. SD=Standard deviation, S=Screw, SW=Screw and washer, ΔATDD and ΔTTDD=Magnitude of change in ΔATD and ΔTTD, ATD=Articulo-trochanteric distance, ΔATD=ATD contralateral–ATD treated, ΔATDD=ΔATD difference, TTD=Trochanter-trochanter distance, ΔTTD=TTD contralateral–TTD treated, ΔTTDD=ΔTTD difference

levels not observed, some amount inhibition of GT growth was observed to compare efficacy of S, SW, and EP.

S and EP have different biomechanical properties on inhibiting growth plate. While S directly compresses the growth plate, EP tethers the growth plate according to the tension band principle.<sup>3,13</sup> In an animal study, outcomes of S and EP on inhibiting growth of inferomedial of femoral head physis were compared. The changes of the femoral neck-shaft angle and the histological changes of growth plate were evaluated. Only the S was resulted in a statistically significant decreased neck-shaft angle, with clear histologic changes in the growth plate. The study suggested that implantation of S is more effective than an EP in decreasing the neck shaft angle in skeletally immature hips.<sup>12</sup> Furthermore, in this study, S and SW had remarkable outcomes on inhibiting growth of GT. However, in EP, we could not observed any significant change on

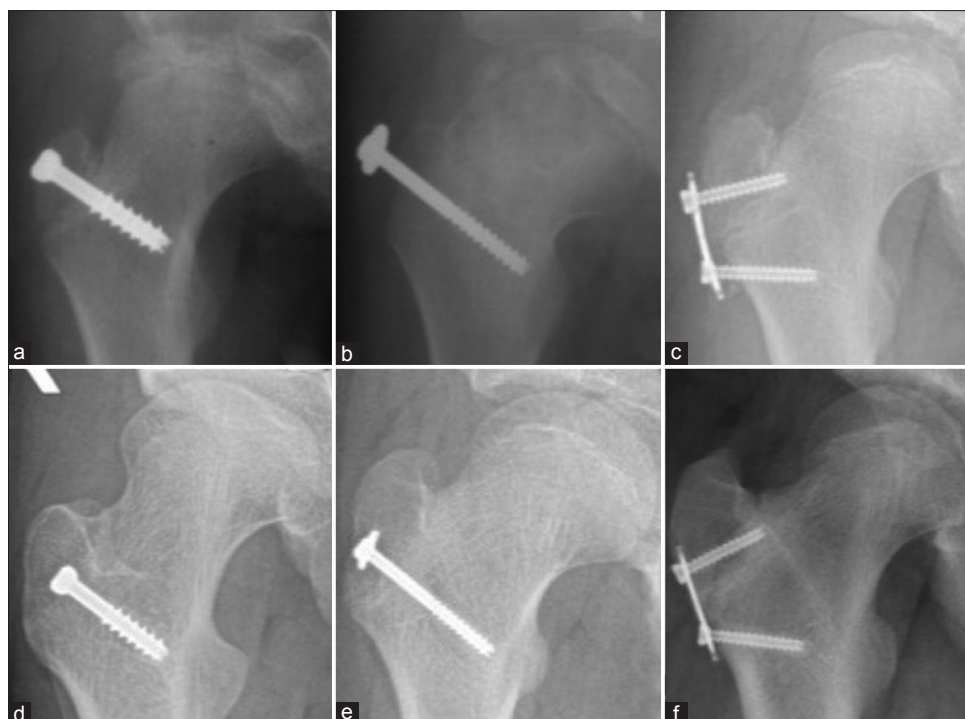
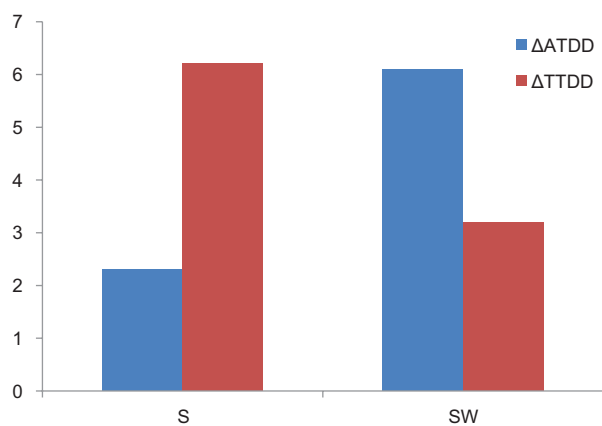


Figure 2: Embedding of implants: Implants become covered by bone on final radiographs. (a-c) Initial radiographs of 11, 8, and 9-year-old cases respectively. (d-f) Final radiographs of same patients five years later

**Table 9: Mean values of Articulo-trochanteric distance contralateral–Articulo-trochanteric distance treated difference and Trochanter-trochanter distance contralateral–Trochanter-trochanter distance treated difference data of initial and final radiographs (mm)**



S=Screw, SW=Screw and washer, ATD=Articulo-trochanteric distance,  $\Delta$ ATD=ATD contralateral–ATD treated,  $\Delta$ ATDD= $\Delta$ ATD difference, TTD=Trochanter-trochanter distance,  $\Delta$ TTD=TTD contralateral–TTD treated,  $\Delta$ TTDD= $\Delta$ TTD difference

inhibiting growth of GT. These results may be related to configuration of implants on growth plate. According to these results, it seems that S and SW, which directly compress growth plate have greater effect on inhibiting growth of GT than EP, which tethers growth plate.

Patients who have orthopedic implants may later require obtaining magnetic resonance imaging, computed tomography studies or adult reconstruction and for these reasons implant removal may be needed. In some instances, implant removal can be difficult or may adversely affect the outcome.<sup>15,16</sup> Removal of an embedded implant may be more challenging than an exposed implant.<sup>16</sup> When comparing S and SW in terms of inhibiting GT growth, outcomes were similar on inhibiting growth of GT. In addition, we observed much higher rates of embedded screw head in S (92%) than SW (10%) final radiographs [Figure 2]. We believe that removal of an embedded implant may be challenging and it may complicate the removal procedure. Therefore, it is reasonable to apply SW rather than using S alone when considering implant removal in future.

Two patients in EP had revision surgery due to loosening of implants. In contrast with S and SW, relatively having a broad, not well-adapting surface on GT may be a reason of loosening of EP.

Growth of GT is based on appositional growth in the superior portion of GT and longitudinal growth of the metaphyseal growth plate. Each growth type contributes to the growth of GT equally. Therefore, in case of a complete arrest on metaphysis, it could theoretically arrest 50% of growth of GT.<sup>3,6,10,11</sup> In this study, we observed statistically significant difference between groups in  $\Delta$ TTD, but the magnitude of differences was small in terms of radiological measurements. This result can be explained by the relatively small growth potential of GT.

Furthermore, the study group has relatively high mean age for effective GTA, which is limitation of this study. Studies with younger patients may show higher differences in terms of radiological measurements; therefore, EP may also show statistically significant growth inhibition. The growth of GT may be affected by changes of direction of muscle pull that resultant by structural changes of upper femoral morphology in the course of LCPD or after pelvic and femoral osteotomies. However, to the best of our knowledge, this scenario was not comprehensively studied yet, and we believe that it has to be revealed. Therefore, we are unable to state that heterogeneity of this study group in terms of LCPD stages and history of pelvic and femoral osteotomies are confounding parameters or not. We think that further studies should be done to clarify the effect of morphological changes resultant after pelvic and femoral osteotomies or in the course of LCPD.

## Conclusion

According to this study, we can state that radiological outcomes on slowing down GT growth of S and SW are similar and greater than EP. GTA can slow down but does not totally prevent overgrowth of GT in the study group. If implant removal is planning in future, we suggest using SW together rather than using screw alone, to reduce embedding of the screw which may be challenging.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

## Financial support and sponsorship

Nil.

## Conflicts of interest

There are no conflicts of interest.

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