Minimally invasive (MIS) Tönnis osteotomy– A technical annotation and review of short term results

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ABSTRACT

Aims: We detail a modified single incision approach to perform the Tönnis triple pelvic osteotomy by a minimally invasive approach.

Patients and Methods: 12 children underwent minimally invasive Tönnis Osteotomy. There were five boys and seven girls in this study group. Average age was 11 years (9–15 years) at the time of surgery. Mean follow-up was 20.5 months (13–39 months).

Results: The average preoperative Antero-Posterior (AP) Centre Edge (CE) angle was -8.8° (-38.6° – 18°), the average post-operative AP CE angle was 29.7° (25.1° – 43.7°). The average preoperative lateral CE angle was -4.7° (-16° – 0°), the average postoperative Lateral CE angle was 28.5° (21.3° – 37.4°). The Sharp's angle before and after surgery were 55.7° (51.3° – 66°) and 32.4° (16.1° – 40.1°) respectively. The mean Tönnis angle before and after the osteotomy were 28.86° (19.7° – 43.4°) and 6.3° (0.5° – 9.4°) respectively. There was one major complication with sciatic nerve palsy which is in the recovery phase on followup and six minor complications including two cases of transient lateral femoral cutaneous nerve injury, two cases of ischial non-union, over granulation of the wound in one case, and metalwork irritation in one case.

Conclusion: We have described a minimally invasive Tönnis osteotomy as a viable option based on our results. This technique is recommended for those who are conversant with the traditional pelvicosteotomies.

1. Introduction

Triple pelvic osteotomy has been a key technique for correction of acetabular dysplasia. First described by Le Coeur in 1965, it has since undergone multiple modifications and refinements.¹ A common feature of the early techniques is that they described osteotomies of the pubic ramus and ischium far away from the acetabulum, thereby restricting the fragment mobility. It was Tönnis and Carolioz who demonstrated that the juxta-acetabular ischial cut could untether the acetabular fragment from the tight grasp of sacrospinous and sacrotuberous ligaments, resulting in greater mobility of the acetabular fragment.²

The original modification by Tönnis used three separate approaches; one for each individual osteotomy.² However the literature is replete with various modifications of this approach.^{3–7} Most of the techniques involved a posterior or groin incision to perform the ischial cut. Inspired by the Bernese approach to the Peri-Acetabular osteotomy, Zaltz described the single incision triple pelvic osteotomy with the ischial cut passing through the lesser sciatic notch, however this does not prevent tethering of the acetabulum by the sacrospinous ligament.^{8,9}

We describe a minimally invasive Tönnis osteotomy by the Sheffield approach, in which the ischial cut is performed above the ischial spine through a single anterior incision. The sacrospinous ligament is not attached to the fragment thereby facilitating its maximum mobility. Furthermore, all osteotomies are performed through a single approach, obviating the need for patient repositioning during the procedure. We intend to share our experience with this approach for the management of acetabular dysplasia in children.

2. Material and methods

2.1. Outcome assessment

A search in the hospital database for pelvic osteotomies performed between 2006 and 2015 retrieved 320 cases. Of these, 12 patients had undergone minimally invasive Tönnis osteotomy and formed the study group. Those who underwent the traditional two-incision approach were excluded. This study was approved by the institutional audit and ethical committee. The inclusion criteria were symptomatic dysplasia in

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patients who underwent minimally invasive Tönnis osteotomy by the Sheffield approach, no evidence of osteoarthritis (Tönnis 0 or 1), good range of motion in the hip joint.

Case notes were reviewed to collect demographic details, indications for surgery and perioperative data including operative time, blood loss and postoperative transfusion requirements. All patients/carers completed self-assessment functional questionnaires including the Modified Harris Hip Score (MHHS) and the Non-Arthritic Hip Score (NAHS) preoperatively and again before last follow-up. The radiographs were retrieved from the Picture Archival and Communication Systems (PACS).

Analysis was performed of pre and postoperative radiographs to assess the extent of dysplasia. Antero-posterior (AP) and false profile pelvic radiographs were reviewed to measure the centre edge angle (CE), Sharp's angle and the Tönnis angle. Paired T test was used to check the differences observed and significance was set at p value ≤ 0.05 .

2.2. Surgical technique

All operations were performed by the senior author (SSM), involving a technique similar to that of the minimally invasive Peri-Acetabular Osteotomy (PAO) described by Troelsen et al.¹⁰.

Patients are positioned supine on a special Macquet radiolucent attachment to the operating table. Preoperative image intensifier screening of the operative hip is performed to obtain baseline AP and false profile views (Figs. 1 and 2). Effective planning, positioning of the image intensifier and communication with the radiographer is key to ensure required views can be easily obtained during surgery and thereby reduce unnecessary radiation exposure and time loss.

Sterile preparation of the entire lower limb from subcostal region to the foot is done. A lumbar plexus block is performed preoperatively for the majority of cases. This helps the patients postoperatively, particularly in children with spasticity. The entire lower limb is then prepared and draped extending proximally to the subcostal region. A 5–7 cm incision centered on the anterior superior iliac spine is made with 3 cm below and 4 cm above it in the groin crease (Fig. 3a and b). The sartorius and tensor fascia lata interval is identified and the lateral femoral cutaneous nerve identified and retracted medially. The muscles on the inner table of the ilium are elevated subperiosteally with a sharp periosteal elevator up to the pelvic brim, and distally with a Cobb's elevator to the quadrilateral plate. The medial soft tissues are retracted with a curved radiolucent blunt Hohmann retractor.

Fig. 1. Pre-operative AP view of a hip [with open triradiate cartilage] on table screening.

Fig. 2. Pre-operative false profile view of a hip [with open triradiate cartilage] on table screening.

Fig. 3. (a) On-table marking of the skin incision for MIS Tönnis osteotomy. (b) Follow-up clinical picture to demonstrate the scar.

The superior pubic ramus is dissected subperiosteally with a sharp periosteal elevator. Further elevation is done with diathermy if the periosteum is densely adherent which is the case in most of the paediatric age group patients. It's absolutely critical to stay subperiosteal as we know the anastomosis between the obturator artery and the external iliac artery through the corona mortis is at the level of the iliopectineal eminence and damage can lead to torrential bleeding with intra-pelvic retraction of the vessels. This can be very difficult to manage. The key to avoid this is to stay subperiosteal. The medial extent of the dissection is 1–2 cm beyond the iliopectineal eminence.

Strict subperiosteal dissection also pushes the iliopsoas and the neurovascular bundle medially with the muscle acting as an intermediary layer between the retractor and vessels. A sharp Hohmann retractor is placed medial to the iliopectineal eminence and impacted into the superior pubic ramus. Further subperiosteal dissection of the anterior and posterior surfaces of the superior pubic ramus is made and a curved blunt Hohmann retractor is inserted posterior to the superior pubic ramus into the obturator foramen.

Anteriorly the rectus femoris attachment is kept intact and the fascia over the rectus femoris is released further distally to get space for the extracapsular dissection. The dissection is done with Cobb's elevator anteromedial to the capsule to create the plane between capsule and iliocapsularis, capsulus minimus. The Cobb's elevator is let to take the extracapsular path below the obturator externus medially to reach the infracotyloid fossa. The Cobb's is used to raise the periosteum on the ischium and is swapped with a fish tailed 30° angled Ganz osteotome. The C-arm is stationed for false profile view as decided by preoperative screening.

The fish tailed osteotome handle should face the same side shoulder. The cut is directed superiorly just below the infracotyloid notch to reach above the ischial spine (we call it 'the Sheffield cut') (Fig. 4). The medial bridge is first cut and then the osteotome is redirected to cut the lateral bridge. Once the cut is completed and satisfactory under x ray the osteotome is taken out and the anterior pubic dissection carried out. Once the periosteum is elevated anteriorly a sharp curved Hohmann retractor is placed subperiosteally anteriorly into the obturator foramen.

Once the pubic ramus is erased subperiosteally, the superior pubic ramus is cut with a straight osteotome from supero-lateral to infero-medial direction. The cut should stay medial to the iliopectineal eminence, preventing the cut becoming intra-articular. Diathermy is used to make a small 2 cm long release of the origin of the abductors on the outer crest to allow a blunt Hohmann retractor to be slid to the sciatic notch and the outer table is raised subperiosteally. Bleeding is expected

Fig. 4. Ischial cut from the infracotyloid notch reaching the greater sciatic foramen (the Sheffield cut).

Fig. 5. a and b: Shanz screw placement in the AIIS to initiate the fragment mobilization.

and staying subperiosteal is absolutely critical again.

The Anterior Inferior Iliac Spine (AIIS) is identified and the sciatic notch is protected from both inside and outside the pelvis. A power saw is used to cut the iliac wing up to the sciatic notch. The deep end of the cut is completed with an osteotome. The completeness of the cut is checked with a lamina spreader. A Steinmann pin is inserted into the anterior inferior iliac spine to mobilize the fragment (Fig. 5a and b). Any further tether needs to be addressed before final positioning. If the ischial cut is not free at the deeper end, it might need untethering with the angled osteotome from inside the pelvis (Fig. 6 or from below Fig. 9). Due care is needed to avoid any neurovascular injury by staying subperiosteal. The correction of dysplasia is then undertaken. The fragment is moved to cover anteriorly by flexing the fragment, lateral

Fig. 6. Ischial cut from inside pelvis for the final untethering. Not mandatory, but may be needed if there is a deep tether.

Fig. 7. Postoperative on-table screening images. AP view demonstrating the corrections.

Fig. 8. Postoperative on-table screening images. False profile view demonstrating the corrections.

Fig. 9. Untethering of the ischial cut from below.

CE angle is corrected by abducting the fragment and version is taken care by not retroverting (excessive external rotation) the fragment. Once the desired correction is achieved as visualized by the C-arm fluoroscopy images, the fragments are fixed with long 4.5 mm pelvic fixation screws (Figs. 7 and 8). Once fixation is stabilized, on table hip range of motion is checked to look for impingement. Radiographs are done in both AP and false profile view to check for the adequacy of correction and to rule out retroversion.

Cell salvage is used throughout the procedure and Tranexamic acid is given at the start of the procedure. The wound is closed by first suturing back the inguinal ligament, the external oblique and abductors back to the iliac crest, followed by subcutaneous and skin sutures.

Postoperative protocol included 48 h of Patient Controlled Analgesia (PCA) and lumbar plexus infusion. Mobilization with touch weight bearing after 48 h for the first six weeks. Repeat radiographs after 6 weeks and to progress to full weight bearing based on the radiographic healing. The patients were scored for their hip function before and after surgery when they returned for follow-up at 1 year after surgery.

3. Results

12 patients formed the study group. (Table 1) All the patients with hip dysplasia had undergone previous open reduction for congenital hip dislocation. The child with post septic hip dysplasia had previously undergone an open arthrotomy and washout of the joint. There were five boys and seven girls in this study group. Average age was 11 years (9–15 years) at the time of surgery. Mean follow-up was 20.5 months (13–39 months). Two cases were started as PAO (Peri-Acetabular Osteotomy) and converted to Tönnis as the posterior column sustained an intraoperative fracture. Eight patients concurrently underwent a proximal femoral osteotomy for femoral dysplasia.

The average preoperative Antero-Posterior (AP) Centre Edge (CE) angle was -8.8° (-38.6° to 18°), the average post-operative AP CE angle was 29.7° (25.1° to 43.7°). The average preoperative lateral CE angle was -4.7° (-16° to 0°), the average postoperative Lateral CE angle was 28.5° (21.3° to 37.4°). The Sharp's angle before and after surgery were 55.7° (51.3° to 66°) and 32.4° (16.1° to 40.1°) respectively. The mean Tönnis angle before and after the osteotomy were 28.86° (19.7° to 43.4°) and 6.3° (0.5° – 9.4°) respectively. Paired students *t*-test showed that the observed difference in the angles after surgery were statistically significant $p \leq 0.05$ (Table 2).

Table 1
Patient demographics for the MIS Tönnis by the Sheffield approach.

Patient	Age (years)	Sex	Diagnosis	Femoral procedure	Complications	Blood loss
1	13	M	CMT type 1A	Varus shortening derotation osteotomy	Transient LFCN sensation loss, ischial non-union	Cell salvage 245 ml
2	9	F	Congenital short femur	Wagner's osteotomy proximal femur	Delayed union femoral osteotomy which needed bone grafting	Cell salvage 131 ml
3	9	M	CDH	Nil	Nil	Cell salvage 120 ml
4	15	M	Asymmetric diplegia, developmental delay and previous meningococcal meningitis.	Nil (PAO converted to Tönnis on table)	Ischial non-union – asymptomatic	Cell salvage 236 ml
5	10	F	Dystonic quadriplegic cerebral palsy	Proximal femoral shortening and varus derotation osteotomy	Nil	Cell salvage 123 ml
6	12	F	CDH	Proximal femoral shortening and varus derotation osteotomy	Femoral plate irritation post op	Cell salvage 250 ml
7	10	M	Septic arthritis hip with dysplasia of acetabulum and femoral head	Proximal femur shortening and derotation osteotomy	Screw migration	Cell salvage 225 ml
8	12	F	Primary acetabular dysplasia	Nil. PAO converted to Tönnis	Inferior pubic ramus stress fracture, transient LFCN palsy	Cell salvage 126 ml
9	12	F	CDH	Proximal femoral shortening and varus derotation osteotomy	Painful non-union of proximal femur	Cell salvage 201 ml
10	10	M	Down's syndrome	Proximal femur shortening and varus derotation osteotomy	Over granulation of the iliac crest wound	Cell salvage 98 ml
11	11	F	CDH	Nil	Sciatic nerve palsy, recovered MRC grade 4 dorsiflexion at 11 months.	Cell salvage 105 ml
12	9	F	CDH revision operation, with residual hip subluxation	Proximal femur shortening and derotation osteotomy	Nil	Cell salvage 110 ml

LFCN- Lateral Femoral Cutaneous Nerve. CMT- Charcot-Marie-Tooth Disease. CDH- Congenital Hip Dislocation. PAO- Peri-Acetabular Osteotomy

Table 2

Pre and post operative radiological dysplasia parameters and scores.

	Pre-operative value	Post-operative value	p- value
Tönnis angle	28.8° ± 6.5	6.3° ± 5.5	< 0.00001
Sharp's angle	55.7° ± 3	32.4° ± 6.5	< 0.00001
AP centre edge angle	−8.8° ± 15.5	29.7° ± 8.7	< 0.0001
Lateral centre edge angle	−4.7° ± 3.9	28.5° ± 6.4	< 0.00001
MHHS	55.01 ± 12.27	83.44 ± 32.2	0.1096
NAHS	60.4 ± 10.7	91.25 ± 21.23	0.2540

The mean operating time for combined procedures was 223 min (120–310 min) and 150 min (120–190 min) for isolated Tönnis osteotomies. Three patients needed blood transfusions due to intraoperative blood loss. Average intraoperative blood loss as calculated from the cell-saver circuit was 552 ml (100–1600 ml). The mean pre and post-operative haemoglobin levels were 128.9 g/L (114–145) and 99.2 g/L (74–117) respectively.

None of the isolated Tönnis procedures (n = 4) required blood transfusions and only three of the seven patients who concurrently underwent femoral procedures required a single unit transfusion post-operatively.

The mean preoperative Modified Harris Hip Score (MHHS) and the Non Arthritic Hip Score (NAHS) were 53.2 and 59 respectively. The mean postoperative MHHS and NAHS were 76.1 and 87.2 respectively (Table 2). Children with cerebral palsy, and Down's syndrome were excluded from this scoring. 100% of the carers for these children said they would recommend this procedure for the other side if needed.

Complications were classed in to major and minor. Major complications included a sciatic nerve palsy which recovered in 11 months with MRC grade 4 power of dorsiflexion of foot, tibialis anterior and extensor hallucis longus. Two patients had delayed union of the proximal femoral osteotomy which required revision fixation with bone grafting. Minor complications included two cases of transient lateral femoral cutaneous nerve injury, two cases of ischial non-union, over-granulation of the wound in one case, and metalwork irritation in one case.

4. Discussion

Our results for minimally invasive Tönnis osteotomy by the Sheffield approach showed adequate correction of the dysplasia. This study aims to describe this Sheffield approach to Tönnis osteotomy.

Steel described his osteotomy through two incisions¹¹; a single anterior incision for the innominate and superior pubic ramus osteotomies and a horizontal incision over the ischium for the ischial osteotomy. Tönnis, however, described a gluteal incision for the ischial osteotomy.² These techniques require positioning the patient in such a way that the approach to the ischium can be performed separately. Furthermore, the use of multiple incisions can have a range of deleterious effects including increased blood loss, operative time and infection risk, as well as increasing pain and cosmetic concerns. In the Sheffield approach, a single 5–7 cm anterior incision is made for all osteotomies, without the need for further incisions or a change in patient positioning.

We embarked on performing this osteotomy after the senior author performed the traditional Ganz osteotomy in 50 cases followed by a large series of minimally invasive periacetabular osteotomies (> 108 cases). Centres with high volumes of such hip preservation procedures could certainly adopt this approach in their practice with ease.

The results from this study showed that a significant correction was achieved in the radiological parameters of hip dysplasia for all patients. A significant improvement in function and pain was also seen in the majority of patients as reflected by the improvement in modified Harris and non-arthritic hip scores. None of the patients undergoing isolated

minimally invasive Tönnis osteotomy required a blood transfusion

Deterioration in functional scores was noted initially in the patient who sustained a sciatic nerve palsy. The authors believe that this complication occurred at the time of the innominate osteotomy; the osteotomy was inadvertently directed superior to the sciatic notch and required redirecting. Though the sciatic notch was protected with a retractor throughout, it is likely that nerve injury was caused by stretch or direct pressure at this time and postoperative MRI had shown the nerve to be in continuity.

Various studies of the triple pelvic osteotomy for acetabular dysplasia reported in the literature have demonstrated excellent correction of the centre edge angle, roof angle and Sharp's angle.^{1,12–14} In line with these reports our series established adequate correction of radiological parameters of acetabular dysplasia in all cases. As demonstrated by the Hailer et al. the results and scores are significantly influenced by the complications encountered in our series as well.¹² Konya et al. established that previous surgery does affect the amount of radiological correction and functional scores.¹⁴ All patients with residual hip dysplasia in our study had undergone previous hip open reduction which might have a bearing on the results. However we don't have a control group to appreciate this effect.

This study is not without limitations. We are presenting the short term outcomes of a relatively inhomogeneous group of patients. However our aim was to demonstrate a new surgical technique which is effective in correcting acetabular dysplasia. Due to the reduced exposure and visualisation of the pelvis, however, experience in pelvic reconstructive surgery and a comprehensive three-dimensional understanding of the pelvic anatomy is required to minimise complications.

Conflict of interest

None.

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