



Risk factors associated with non-union after triple pelvic osteotomy (Toennis and Kalchschmidt technique): a case–control study and review of the literature

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Abstract

Introduction Dysplasia of the hip is a well known cause of secondary osteoarthritis of the hip. The triple pelvic osteotomy (TPO), according to the technique described by Toennis and Kalchschmidt, is a well established procedure to address dysplasia of the hip joint. Non-unions after triple pelvic osteotomies are rare and can occur at each of these osteotomies. The literature is lacking in studies investigating larger group of patients with non-unions after triple pelvic osteotomy. The aim of this study is to evaluate risk factors leading to a non-union after triple pelvic osteotomy.

Methods A total of 53 patients with a non-union after triple pelvic osteotomy were included in this retrospective case–control. In addition, we identified a cohort of randomly selected patients undergoing hardware removal after triple pelvic osteotomy (“union” group) but had not developed non-union as the control group. This control group underwent the same procedure by the same group of surgeons in the same time period. The variables obtained from the review of the two groups were analyzed using appropriate statistical methods including Bivariable Analysis ($p < 0.005$) and Multivariable logistic regression analysis ($p < 0.015$).

Results We identified a total of 53 patients out of the 3269 who had undergone TPO and had developed a non-union. The control group consisted of 117 patients who did not experience a non-union. Bivariable analysis of basic demographic characteristics demonstrated that gender, BMI, smoking, preoperative CE angle and degree of surgical correction did not differ significantly between the groups. There was a statistically significant ($p < 0.05$) difference between age (31.5 ± 9.4 vs. 27.5 ± 9.0 in the non-union and union groups, respectively; $p < 0.001$) and postoperative CE angle (34.4 ± 5.0 vs. 32.8 ± 3.5 in the non-union and union groups, respectively; $p = 0.02$). Multivariable analysis demonstrated that an age over 30 was significantly associated with non-union ($p = 0.01$, OR 2.6, 95% CI 1.3–5.3).

Conclusion Non-unions after TPO are rare. A higher age and higher degree of surgical correction might be associated risk factors for developing a non-union. Furthermore, smoking, obesity and previous hip surgeries might also contribute to developing a non-union after triple pelvic osteotomy.

Keywords Triple pelvic osteotomy · Non-union · Pseudarthrosis · Complication

Introduction

Dysplasia of the hip is a well known cause of secondary osteoarthritis of the hip. The triple pelvic osteotomy (TPO), according to the technique described by Toennis and Kalchschmidt, is a well established procedure to address dysplasia of the hip joint. The goals are a surgical reorientation and biomechanical normalization of the dysplastic acetabulum. Therefore, the whole acetabulum has to be mobilized through osteotomies of the ischium, ilium and pubis. Surgical complications, including non-unions, acetabular osteonecrosis, infection, and nerve and vascular injury can occur.

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Non-unions after TPO are rare with risks ranging from 2.9%–28% [1, 2]. Patients with non-unions after TPO complain about pain on weight-bearing and restrictions in the range of motion [3, 4]. Furthermore, a non-union can lead to a loss of the surgical correction. It is suggested that non-unions may occur because of soft tissue interposition, extensive bone resection with inadequate bone contact, and unstable fixation. Non-unions of the pubis are often asymptomatic and do not require further surgical treatment, whereas non-unions of the ischium, ilium or their combinations need surgical intervention [4–6]. The literature is lacking in studies evaluating risk factors for non-union after TPO. The aim of this study is to evaluate risk factors leading to a non-union after triple pelvic osteotomy.

Methods

Study design

Due to the rare occurrence of non-union, we performed a case–control study.

Patient sampling

We used ICD-9 codes and ICD-10 codes to identify all TPOs ($n = 3269$) performed at the Department of Orthopedics, Klinikum Dortmund-Mitte, Germany during years 2001 to 2016. Patient charts, including radiographs from a total of 257 patients were evaluated retrospectively. Non-union was defined as an absence of bony trabeculation across the osteotomy surface for a minimum of 6 months.

Cases were selected as all patients during this time period, who experienced a postoperative non-union after TPO. The control group represented a random sample of patients undergoing hardware removal after TPO who did not experience a non-union between January 1, 2017 and December 31, 2017. This control group underwent the same procedure by the same group of surgeons. To limit the selection bias of this control group, the demographic data of all patients who underwent a triple pelvic osteotomy between January 1, 2013 and December 31, 2017 ($n = 925$; mean age 26.7 ± 8.8) were collected.

Study criteria

Cases and controls were included if surgery was performed in our Department by the same group of surgeons. Patients were excluded (1) if they underwent the TPO in a different hospital, (2) if a different osteotomy technique was used, and (3) if patient had a previous surgery on the hip joint (Fig. 1).

Surgical technique and post-operative management

In all patients, osteotomies were performed according to the technique described by Toennis and Kalchschmidt [7]. All patients were advised to remain non-weight bearing for 12 weeks. All patients were treated with thrombosis prophylaxis for the period of limited weight bearing. Joint movement was limited up to 30° for ab- and adduction, no external rotation, and a maximum flexion of 60° . Active internal rotation was demanded. When radiographic signs of consolidation appeared 6 weeks postoperatively, flexion up to 90° and abduction were permitted. Pre- and postoperative radiographs were analyzed using anterior–posterior view (AP), faux profile views and CT scan, when available, to evaluate non-union location and degree of correction using the center-edge angle.

Risk factors

The following risk factors were ascertained from the patients' medical records: age, gender, BMI, tobacco use, degree of surgical correction, comorbidities (cognitive disability, cardiovascular, epilepsy, asthma, hypothyroidism, auto-immune disorder, depression, neuromuscular disorders, NSAR abuse, diabetes mellitus, and allergies). We dichotomized the variables age (≥ 30 years vs. < 30 years) and degree of surgical correction ($\geq 15^\circ$ vs. $< 15^\circ$).

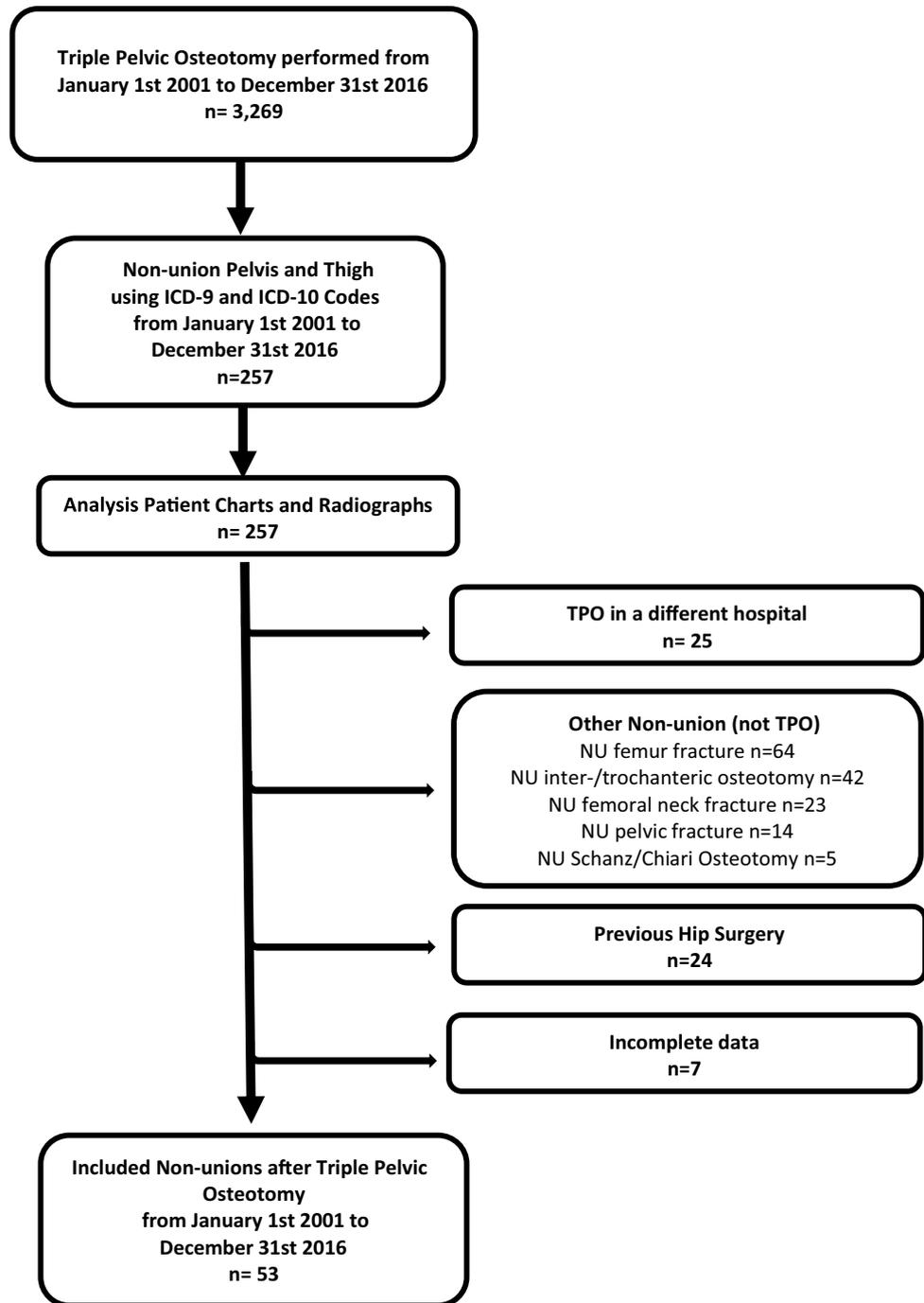
Statistical analysis

Bivariable analysis was performed to compare cases and controls with risk factors. For categorical variables, frequency counts were computed and presented along with their percentages. For continuous variables, means were computed and presented along with their standard deviation. To compare categorical variables, the Chi square test was used. For continuous outcomes, a t test was used. For the multivariable analysis comparing cases to controls, we performed a backwards stepwise logistic regression setting $p < 0.15$ as the cutoff for variable retention to generate odds ratios (OR) and 95% confidence intervals (CI). All analyses were performed using Stata 13.1.

Results

We identified a total of 53 patients out of the 3269 who had undergone TPO and had developed a non-union (Table 1).

The control group consisted of 117 patients who did not experience a non-union. Bivariable analysis of basic demographic characteristics demonstrated that gender, BMI,

Fig. 1 Flow diagram showing results of patient search

smoking, preoperative CE angle and degree of surgical correction did not differ significantly between the groups. (Table 2). There was a statistically significant ($p < 0.05$) difference between age (31.5 ± 9.4 non-union vs. 27.5 ± 9.0 union; $p < 0.001$) and postoperative CE angle (34.4 ± 5.0 non-union vs. 32.8 ± 3.5 union; $p = 0.02$).

Multivariable analysis demonstrated that an age over 30 was significantly associated with non-union ($p = 0.01$,

OR 2.6, 95% CI 1.3–5.3), Table 3. The degree of surgical correction ($p = 0.06$, OR 2.1, CI 0.97–4.7), smoking ($p = 0.147$, OR 1.8, CI 0.82–3.8), neuromuscular disorders ($p = 0.09$, OR 7.5, CI 0.72–79.4), depression ($p = 0.09$, OR 8.6, CI 0.70–107.1) and coagulation disorders ($p = 0.08$, OR 9.2, CI 0.75–112.1) were all retained in the final model (Table 3).

Table 1 Overview of non-union location, type of nonunion, surgical treatment and follow-up

Non-union	<i>n</i> = 53	%
<i>Location</i>		
Pubis	12	22.6
Ischium	2	3.8
Ilium	8	15.1
Pubis + ischium	13	24.5
Pubis + ilium	10	18.9
Triple non-union	8	15.1
<i>Atrophic/hypertrophic</i>		
Atrophic non-union	38	71.7
Hypertrophic non-union	15	28.3
<i>Surgical treatment</i>		
Conservatively	2	3.8
Re-correction acetabulum	3	5.7
Re-osteosynthesis + bone grafting	48	90.6
Time from tpo to non-union surgery	15.8 months (5.0–48.0)	

Types of non-union

There were 12 patients (22.6%) with non-union of the pubis, two cases with non-union of the ischium (3.8%) and eight (15.1%) with non-union of the ilium. In 13 (24.5%) patients, double non-union of pubis and ischium occurred. A double non-union of pubis and ilium was seen in ten (18.9%) cases. Eight (15.1%) patients had a triple non-union, including all osteotomies. 38 (71.7%) of the patients had an

atrophic non-union and 15 (28.3%) a hypertrophic non-union (Table 1).

Management of non-unions

Two patients with an asymptomatic non-union of the pubis were treated conservatively. In three cases, a re-osyoteosynthesis was necessary due to a loss of correction. 48 (90.6%) of the patients underwent surgical treatment including debridement, re-osteosynthesis, and bone grafting. Mean time from triple pelvic osteotomy to revision surgery was 15.8 months (5.0–48.0). 51 patients needed surgical intervention to address the non-union (Table 1).

Discussion

Pelvic osteotomies are an established treatment for dysplasia of the hip, especially for younger patients without osteoarthritis. In this study, we reported 53 patients with a non-union after triple pelvic osteotomy. The reported risk in the literature ranges from 2.9 to 28%. However, to our best knowledge, less than 100 cases (Table 4) are reported in the literature [2–4, 7–21]. Available data from studies investigating risk factors are lacking.

Our results indicate that patients who are older than the age of 30 years and have a post-operative correction $\geq 15^\circ$ are at significantly higher risk of experiencing a non-union after TPO. We could show that our control group is representative in terms of mean age by collecting the demographic data of all patients ($n = 925$) who underwent a

Table 2 Results from Bivariable Analysis

Variable	Nonunion (<i>n</i> = 53)	Union (<i>n</i> = 117)	<i>p</i> value
<i>Sex</i>			
Female	46 (86.8%)	96 (82.1%)	0.44
Male	7	21	
Age (mean \pm SD)	31.5 \pm 9.4	27.5 \pm 9.0	0.09
BMI (mean \pm SD)	24.6 \pm 4.9	24.3 \pm 4.1	0.70
Tobacco	19 (35.9%)	32 (27.4%)	0.26
Diabetes	1 (1.9%)	0	0.13
Asthma	2 (3.8%)	6 (5.1%)	0.70
Hypothyroidism	2 (3.8%)	7 (6.0%)	0.55
Depression	2 (3.8%)	1 (0.9%)	0.18
Cardiovascular disease	1 (1.9%)	1 (0.9%)	0.56
Cognitive disability	2 (3.8%)	0	0.04
Coagulation disorder	2 (3.8%)	1 (0.9%)	0.18
Neuromuscular disorder	3 (3.8%)	1 (0.9%)	0.06
Cognitive disability	2 (3.8%)	0	0.04
CE angle pre-operative (mean \pm SD)	16.1 \pm 5.5	13.6 \pm 10.6	0.11
CE angle post-operative (mean \pm SD)	34.4 \pm 5.0	32.8 \pm 3.5	0.02
Degree of surgical correction (mean \pm SD)	18.3 \pm 5.5	19.4 \pm 10.4	0.45

Table 3 Results from the multivariable logistic regression estimating the effect of several risk factors for non-union retaining all variables with $p < 0.15$

Variable	OR	95% CI	<i>p</i> value
Age (≥ 30 years vs. < 30 years)	2.6	1.3–5.3	0.01
Degree of surgical correction (≥ 15 vs. < 15)	2.1	0.97–4.7	0.06
Smoking	1.8	0.82–3.8	0.15
Neuromuscular disorder	7.5	0.72–79.4	0.09
Depression	8.6	0.70–107.1	0.09
Coagulation disorder	9.2	0.75–112.1	0.08

TPO over 5 years (mean age 26.7 ± 8.8 vs. 27.5 ± 9.0). Thought not statistically significant due to the low event rate of non-union, smoker and patients with depression, neuromuscular and coagulation disorders, appear to be at increased risk of non-union. The efficacy of bone healing is inversely related to age. Furthermore, Vukasinovic et al. also reported a significant age difference in patients with non-unions (20.2 ± 27.1 years) and patients without non-unions (15.5 ± 4.67 years; $p = 0.029$) [1].

All studies reporting non-unions after TPO show a degree of correction $\geq 18^\circ$ (3, 7–14, 16, 21). Our hypothesis is that a higher degree of correction leads to an inadequate bone contact and increases the risk of developing a non-union [10]. Toennis and Kalchschmidt believed the location of the osteotomies and the angle of the cuts have an influence in the rate of non-unions [22]. Furthermore, Tschauner et al. reported that an unstable fixation can lead to a non-union [4]. Vukasinovic et al. reported that non-union occurred more frequently when a saw (4/12) was used for osteotomy compared with when a chisel was used (2/64; $p = 0.003$). We used a saw in all patients, but made sure to avoid extreme heat by dripping water and used a screw for pubis fixation, which leads to an improved rotation of the pubis and better medialization of the joint [22].

Smoking did not reach statistical significance in our analysis, likely due to the small proportion of smokers; however, there is evidence that smoking might be risk factor for developing a non-union [23–26]. Tschauner et al. reported that three out of five patients with a painful double non-union were heavy smokers [4]. In our study, 19 out of 53 patients (35.8%) were smokers.

The only study to compare our BMI of 24.6 kg/m^2 is reported by Hailer et al. They reported non-unions after triple pelvic osteotomy in 13 out of 66 patients (incidence 28%) with a mean age of 23 years and a BMI of 22 kg/m^2 . There is strong evidence in the literature that being overweight (BMI 25–30 kg/m^2) significantly affects bone healing [27–29]. The high incidence of non-unions may be mitigated by the fact that Hailer et al. also included patients with previous hip surgery [3]. Due to this fact, a comparison is difficult

to make. But it suggests that previous hip surgery might be a risk factor for non-unions.

We failed to reach statistical significance in patients with neuromuscular disorders, depression and coagulation disorders. Nevertheless, depression and psychiatric disease has been reported to be associated with decrease pain relief, satisfaction, 1-year mortality and a significantly increased medical and surgical complication rate in patients undergoing total hip arthroplasty [30–32]. Furthermore, the majority of patient with neuromuscular disorders is not able to implement partial weight-bearing and we recommend to individualize the postoperative treatment [33].

Toennis reported that isolated non-unions of the pubis often remain asymptomatic [34]. Furthermore Abdulmonem et al., Frick et al., Vukasinovic et al., Janssen et al. and van Hellemond et al. reported cases of painless non-unions [10–12, 15, 16]. There were only two asymptomatic non-unions of the pubis in our study. We follow-up the great majority of the patients to schedule the hardware removal 1 year after triple pelvic osteotomy. Nevertheless, there can be asymptomatic non-unions we have missed.

Based on the results of our data, patients at higher risk of non-union after TPO are those age 30 and above, those with a correction > 15 degrees, patients who have a diagnosis of depression and who have neuromuscular or coagulation disorders. Other factors not included in our study such as previous hip surgery and smoking should also be considered. These patients should be considered for primary bone grafting.

Limitations

This study has several possible limitations. First, it is an observational case–control study so there is potential for bias or residual confounding from factors we did not measure. Since non-union is so rare, a randomized trial or prospective cohort study would be time and cost prohibitive. The advantage of case–control studies is that risk factors for rare outcomes can be estimated with smaller sample sizes. In the end, our sample size was still slightly limited in that our odds ratios for risk factors retained in our final model had very wide confidence intervals. This despite including all non-unions that occurred at our institution over a 15-year period. Nevertheless, patients suffering a non-union might have been treated in a different hospital. The validity of a case–control study hinges on the selection of the controls. Our controls were patients from the same institution who had a clinic visit for hardware removal, but did not experience a non-union. Despite these patients being recruited over a 1-year period, we have no reason to believe that they were different from the cases with respect to their propensity for non-union. However, since we did not take a random sample

from the 15 year period, some bias is possible and likely to cause an attenuation of the odds ratios since these were patients coming back to the hospital. Therefore, we feel our risk factor effect estimates are conservative.

Conclusion

Non-unions after TPO are rare. A higher age and higher degree of surgical correction might be associated risk factors for developing a non-union. Furthermore, smoking, obesity and previous hip surgeries might also contribute to developing a non-union after triple pelvic osteotomy.

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Compliance with ethical standards

Conflict of interest The authors declare no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Appendix

See Table 4.

Table 4 Overview of the existing literature and the reported cases of non-unions after triple pelvic osteotomy

Study	<i>n</i>	Mean age (range)	Localisation	BMI	Degree of correction (pre/post)	Treatment	Time to revision	Comments
This study (2017)	<i>n</i> = 53/3269	31 (16–51)	pub: <i>n</i> = 12; isch: <i>n</i> = 2; ilium: <i>n</i> = 8; triple: <i>n</i> = 8; pub + isch: <i>n</i> = 13; pub + ili: <i>n</i> = 10	24.6	22.5° (10.6°/33.1°)	<i>n</i> = 51 reosteosynthesis + bone grafting	15.8 months	Atrophic <i>n</i> = 38 Hypertrophic <i>n</i> = 15
Hailer et al. [3]	<i>n</i> = 13/66	23 (8–44)	pub: <i>n</i> = 6; isch: <i>n</i> = 2; pub + isch: <i>n</i> = 5	22	18° (14°/30°)	None		22 pat. underwent previous hip surgery
de Kleuver et al. [17]	<i>n</i> = 4/51	28 (14–46)			19° (9°/28°)			Nu after major correction
Hsin et al. [8]	<i>n</i> = 2/22	24 (12–41)	pubis: <i>n</i> = 2		19° (9°/23°)	1 × conservative 1 × plate + bone grafting		
Kirschner et al. [9]	<i>n</i> = 6/48	24 (11–43)	pub: <i>n</i> = 3; isch: <i>n</i> = 2; pub + isch = 1		21.6° (10.6°/32.2°)	2 × bone grafting 1 × bone grafting + osteo		
Tschauner et al. [4]	<i>n</i> = 13/409	25.7 (10–51)	pub: <i>n</i> = 8; pub + isch: <i>n</i> = 5			pub: asymp pub + isch: stabilization	19.4 months	3/5 of double NU smoker (30 cig/d)
Frick et al. [10]	<i>n</i> = 5/23	16 (9–33)	pub: <i>n</i> = 2; isch: <i>n</i> = 2 ilium: <i>n</i> = 1		30° (7°/37°)	2 × revision		2/5 symptomatic
Vukasinovic et al. [11]	<i>n</i> = 7/76	20.2 (± 27.1 SD)	triple nu: <i>n</i> = 1; pub + isch: <i>n</i> = 6		23.5°			All nu asymptomatic
Janssen et al. [12]	<i>n</i> = 1/35	38.6 (24–57)	pub + isch: <i>n</i> = 1		24.4° (10.2°/34.6°)	Conservatively		Nu asymptomatic

Table 4 (continued)

Study	<i>n</i>	Mean age (range)	Localisation	BMI	Degree of correction (pre/post)	Treatment	Time to revision	Comments
Peters et al. [13]	<i>n</i> = 2/60	26 (13–48)	Double nu <i>n</i> = 2		20° (11°/31°)			
Tönnis et al. [7]	<i>n</i> = 1/32	/ (9–33)	pub: <i>n</i> = 1		27.8° (– 10°/17.8°)	Bone graft		
Dungl et al. [14]	<i>n</i> = 19/351	16.5 (9–41)	tri: <i>n</i> = 2; dou: <i>n</i> = 2; isch: <i>n</i> = 8; pub: <i>n</i> = 7		27.7° (7.8°/35.5°)	All Triple NU Osteo + bone grafting		
Abdulmonem et al. (2007)	<i>n</i> = 1	18	Ilium: <i>n</i> = 1			Bone grafting		
van Hellemond et al. [16]	<i>n</i> = 4/48	28 (14–46)	Ischium: <i>n</i> = 3; pubis: <i>n</i> = 1		19° (9°–28°)			All asymptomatic
Rebello et al. [21]	<i>n</i> = 1/31		pubis: <i>n</i> = 1		27.9° (1.1°–39°)			Bernese-type tpo

pub pubis, *isch* ischium, *nu* non-union, *cig* cigarettes, *tri* triple, *dou* double, *isch* isc

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