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# Cigarette smoking delays bone healing

## A prospective study of 200 patients operated on by the hemicallotaxis technique

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**Background** Cigarette smoking is known to impede bone healing. The hemicallotaxis technique is based on an external fixation and delayed healing prolongs treatment and increases the risk of further complications.

**Patients and methods** 200 patients, 34 smokers and 166 nonsmokers, operated on by the hemicallotaxis technique in the proximal tibia for deformities of the knee (knee arthrosis in 186 patients) were consecutively studied. We recorded their preoperative smoking habits, postoperative complications and the duration of treatment with external fixation.

**Results** Half of the smokers and one fifth of the nonsmokers developed complications. Their mean time in external fixation was 96 (SD 20) days. Smokers required an average of 16 days more in external fixation. Delayed healing and pseudoarthrosis were commoner in smokers than nonsmokers. The risk ratio for smokers to develop complications was 2.5, as compared to nonsmokers. ■

Tibia osteotomy by the hemicallotaxis technique (HCO) is based on external fixation. Delayed healing and nonunion prolong the treatment and increase the risk of further complications.

Studies on rabbits have shown delayed bone healing and decreases in bone mineral density (BMD) and strength in the lengthened tibia caused by cigarette smoking (Ueng et al. 1997, 1999). Smoking was the single most important risk factor for the development of serious postoperative complications after elective arthroplasty of the hip and knee (Moeller et al. 2003).

We studied whether smokers had longer healing times and more complications than nonsmokers who underwent HCO.

## Methods

### Patients

In a prospective study 200 consecutive patients (119 men), mean age 53 (18–75) years, were operated on by HCO for knee deformities (Tables 1–2).

The patients' smoking habits (smoker or nonsmoker) were noted preoperatively.

They were called nonsmoker if, at the preoperative examination, they stated that they had never smoked or had stopped smoking more than 6 months previously. 34 (17%) were smokers and 166 (83%) nonsmokers. 7 patients underwent simultaneous bilateral surgery (1 smoker and 6 nonsmokers).

### Hemicallotaxis osteotomy

4 conical pins were inserted, 2 hydroxyapatite-coated in the metaphyseal bone and 2 standard pins (Orthofix®, Bussolengo, Italy) in the diaphyseal bone. The Orthofix® T-garçe was used. The patients were allowed free mobilization and full weight bearing after the operation.

The distraction started 7–10 days postoperatively. 8 weeks after surgery, the fixation was dynamised to stimulate healing of the bone. The first evaluation of bone healing was done 12 weeks

Table 1. Patient characteristics of the study group

	Nonsmokers n=166	Smokers n=34
Gender		
Men	102 (61)	17 (50)
Women	64 (39)	17 (50)
Age		
Mean	53	53
SD	10	6
<50	47 (28)	9 (26)
50–59	77 (46)	22 (65)
60+	42 (25)	3 (9)
Preop HKA-angle in medial cases		
mean	170°	170°
SD	5°	3°
≥171°	71 (45)	16 (49)
<170°	64 (40)	12 (31)
in lateral cases		
mean	187°	189°
SD	5°	4°
≤189°	17 (11)	2 (3)
>190°	5 (5)	3 (12)
BMI		
<25	25 (16)	12 (35)
25–29	77 (48)	13 (38)
30+	58 (36)	9 (27)

Percentages within parenthesis

Preop HKA-angle = Preoperative Hip-Knee-Ankle-angle

BMI = Body mass index

Table 2. Indication for surgery in 200 patients who underwent HCO

	All n=200	Nonsmokers/ smokers n=166/34
Knee osteoarthritis	186	153/32
medial	163	134/29
lateral	20	15/5
pre <sup>a</sup>	2	2/0
Fracture sequelae	8	6/2
Knee deformity	4	4/0
Osteonecrosis	1	1/0
Sequelae of tibia osteotomy	1	1/0

<sup>a</sup> Arthroscopic osteoarthritis with symptoms but no osteoarthritis, according to radiographic Ahlbäck grade I.

postoperatively. If healing of the osteotomy was deemed satisfactory on both the radiographic and ultrasound examinations, the patient did a weight-bearing test—i.e., walked for a few hours or even some days without the instrument, but with the

pins in situ. If no symptoms developed, the pins were removed in the outpatient clinic, but if the patient developed symptoms, the T-garçe was applied again for 2–4 weeks.

### Outcome

We recorded the duration of external fixation (from surgery until the external pins were removed) and the complications, such as delayed healing (> 16 weeks in external fixation), pseudoarthrosis, septic arthritis, deep venous thrombosis, nerves injury, and interrupted treatment (i.e. loose pins due to a pin site infection).

### Statistics

The Analysis Of Variance (ANOVA) test, t-test and Chi-square test were used for the statistical analysis, and the statistical significance was set at  $p < 0.05$ . A multiple logistic regression analysis (checked for potential confounders) was used to estimate the odds ratio (OR) of complications, delayed healing and pseudoarthrosis.

The study was approved by the Ethics Committee, Lund University, Sweden.

### Results

More complications occurred among the smokers than the nonsmokers. 51 patients had one or more complications (delayed healing, pseudoarthrosis, septic arthritis, deep venous thrombosis, nerves injury or interrupted treatment) (34/166 (Table 3) nonsmokers and 17/34 smokers,  $p < 0.001$ ). 12/51 patients had 2 or more complications (7 nonsmokers and 5 smokers,  $p = 0.02$ ). The risk ratio for the smokers who developed complications, as compared to the nonsmokers, was 2.5 (95% CI 1.5–3.9).

Delayed healing and pseudoarthrosis occurred more often among the smokers. The risk ratio for delayed healing was 2.7 (95% CI 1.5–4.7) in the smokers. 8 patients with delayed healing developed pseudoarthrosis. The risk ratio for smokers to develop pseudoarthrosis was 8.1 (95% CI 1.8–42.0) (Table 3). 6 of the patients who developed pseudoarthrosis required additional surgery for healing (5 smokers and 1 nonsmoker) and 2 patients (nonsmokers) healed after low intensity

Table 3. Complications in 200 patients operated on by HCO

	Nonsmokers n = 166	Smokers n = 34	Relative risk (RR) (95% CI) <sup>a</sup>
Delayed healing <sup>b</sup>	25	14	2.7 (1.5–4.7)
Pseudoarthrosis	3	5	8.1 (1.8–42)
Septic arthritis	2	1	2.4 (0.1–34)
Deep venous thrombosis	3	2	3.3 (0.4–23)
Nerve injury	1	0	0 (1.0–84)
Interrupted treatment	3	1	1.6 (0.1–17)

<sup>a</sup> (95% CI) = 95% confidence interval

<sup>b</sup> Includes 5 patients who developed pseudoarthrosis after removal of external fixation.

ultrasound stimulation (Exogen<sup>®</sup>, Tuttlingen, Germany).

In the 3 patients who developed septic arthritis (2 nonsmokers and 1 smoker), the treatment was interrupted and in one patient (nonsmoker), the treatment was interrupted due to loose pins. The mean time in external fixation was 96 (SD 20) days in all patients. The mean time in external fixation for nonsmokers was 94 (SD 18) days and 110 (SD 25.2) days for smokers ( $p < 0.001$ ). The smokers had 16 days ( $p < 0.001$ , 95% CI 7.0–25) longer mean time in external fixation than the nonsmokers. In patients with a frame time >112 days, the smokers had a mean of 17 days more ( $p = 0.004$ , 95% CI 5.5–26) in external fixation than the nonsmokers (Table 4). Among the 7 patients who underwent bilateral HCO in one séance, 3 patients had complications—i.e., 2 had delayed healing, 1 smoker and 1 nonsmoker. And 1 (nonsmoker), with osteonecrosis after treatment for leukemia, developed pseudoarthrosis (rapid loss of correction) in one of the osteotomies.

The multivariate analysis, used to detect potential confounders, showed that cigarette smoking was the greatest preoperative risk factor for complications OR 5.1 ( $p = 0.001$ , 95% CI 2.2–12), delayed healing OR 4.0 ( $p = 0.004$ , 95% CI 1.7–9.5), and pseudoarthrosis OR 8.9 ( $p = 0.02$ , 95% CI 1.7–47.1) (Table 5).

## Discussion

Smokers operated on by HCO for knee deformi-

Table 4. Frame time &gt; 112 days in patients operated on by HCO

	Nonsmokers	Smokers	P-value
Mean (days)	126	143	0.004
SD	13	16	
n	23	11	

ties needed a longer time in external fixation and had more complications, such as delayed healing and pseudoarthrosis than nonsmokers. Half of the smokers developed complications. The risk for the smokers developing complications was 2.5 times higher than in the nonsmokers.

A recent study by Moeller et al. (2003) on patients operated on for arthroplasty of the hip and knee confirmed our findings—i.e., smoking is the greatest risk factor for developing postoperative complications.

The number of smokers (34 of 200 patients) in our material is similar to the percentage of smokers in the Swedish population, 19% (18% men and 20% women) (Mackay and Eriksen 2002).

The mean time in external fixation in patients operated on by HCO has ranged from 79 to 91 days in various studies (Magyar et al. 1998, Klinger et al. 2001, Gerdhem et al. 2002), as compared to our 96 days. These differences may be due to the time when the first examination for healing was done, the methods used to assess healing, the experience in evaluating the healing on radiographs and perhaps the use of ultrasound. The size of the correction and whether bilateral

**Table 5. Relationship of risk factors to complications, delayed healing and pseudoarthrosis in patients operated on by HCO**

	Complications Adjusted OR <sup>a</sup>	Delayed healing Adjusted OR <sup>a</sup>	Pseudoarthrosis Adjusted OR <sup>a</sup>
Gender			
Men <sup>b</sup>	1.0	1.0	1.0
Women	1.4 (0.7–2.9)	1.8 (0.8–4.1)	5.0 (0.8–31)
Age			
<50 <sup>b</sup>	1.0	1.0	1.0
50–59	0.9 (0.4–2.3)	1.0 (0.4–2.6)	0.5 (0.09–3.3)
60+	1.4 (0.5–3.9)	0.9 (0.3–3.0)	1.4 (0.2–12)
BMI			
<25 <sup>b</sup>	1.0	1.0	1.0
25–29	0.7 (0.3–1.8)	0.7 (0.3–2.1)	0.9 (0.1–6.0)
30+	1.2 (0.5–3.1)	1.1 (0.4–3.1)	0.5 (0.06–3.6)
Preop HKA-angle <sup>c</sup>			
medial/lateral			
>171/<189 <sup>b</sup>	1.0	1.0	1.0
<170-/>190	1.8 (0.9–3.7)	1.7 (0.8–3.8)	3.6 (0.6–21)
Smoking			
Nonsmokers <sup>b</sup>	1.0	1.0	1.0
Smokers	4.1 (1.8–3.7)	3.7 (1.5–8.9)	7.5 (1.4–41)

<sup>a</sup> Odds ratio (OR) adjusted simultaneously for all other risk factors listed and 95% confidence interval in parenthesis.  
<sup>b</sup> Reference category.  
<sup>c</sup> Hip-Knee-Ankle-angle preoperatively (varus or valgus).

osteotomies were done in one séance could also account for a longer treatment time. We found no differences between unilateral and bilateral osteotomies or the preoperative HKA-angle, as regards the longer healing time.

Cigarette smoking has been shown to cause slower healing and pseudoarthrosis in tibial fractures, both after closed (Kyro et al. 1993) and surgical treatments (Adams et al. 2001). In closed and grade I open tibial shaft fractures, Schmitz et al. (1999) found statistical differences in clinical and radiographic healing rates in smokers and nonsmokers in patients who underwent intramedullary or external fixation.

Cobb et al. (1994) reported that the relative risk of nonunion after ankle arthrodesis was 4 times higher in smokers. When patients had no known risk factors for nonunion, the risk of nonunion was 16 times higher in smokers.

Examination after a laminectomy and fusion showed more pseudoarthrosis among smokers than nonsmokers (Brown et al. 1986). After ulna-shortening osteotomy, the smokers had longer healing times and nonunion than the nonsmokers.

The mean union rates were 7 months in smokers and 4 months in nonsmokers (Chen et al. 2001). Our study of patients who underwent HCO can be added to the list of treatments showing that smoking is an important risk factor for the development of complications in orthopedic surgery.

In a preoperative smoking intervention study, cessation of smoking from 6–8 weeks preoperatively and 10 days postoperatively reduced the postoperative complications in patients undergoing hip and knee replacement. The smoking cessation group was compared to one with an at least 50% reduction in smoking. The patients who reduced their smoking did not differ from the smoking group in other respects (Moeller et al. 2002). Patients undergoing arthroplasty of the hip and knee who smoked previously had a better short-term outcome than those who were smoking (Lavernia et al. 1999). Glassman et al. (2000) showed that the cessation of smoking after surgery helped to reverse the effects of cigarette smoking on the outcome of spinal fusion.

These studies indicate that smoking cessations both preoperatively and postoperatively decrease

the risk for complications, whereas smoking reduction is not enough to decrease the risk.

The conclusions of the present study were that information about smoking cessations prior to surgery should be an important part of the pre-operative information as well as cigarette smoking should be a factor to consider when selecting patients for callus distraction.

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