

Epoxy-based production of wind turbine rotor blades: occupational dermatoses

A. PONTÉN¹, O. CARSTENSEN², K. RASMUSSEN², B. GRUVBERGER¹, M. ISAKSSON¹ AND M. BRUZE¹

¹Department of Occupational and Environmental Dermatology, Malmö University Hospital, Malmö, Sweden, and

²Department of Occupational Medicine, Herning Hospital, Herning, Denmark

Occupational dermatoses were investigated in a factory producing rotor blades for wind turbines by an epoxy-based process. In a blinded study design, 603 workers were first interviewed and thereafter clinically examined. Based on a history of work-related skin disease, clinical findings of dermatitis, or both, 325 (53.9%) of the workers were patch tested with a specially profiled occupational patch-test series and the European standard patch-test series. Calculated on all investigated workers, 17.1% of the workers were diagnosed with occupational dermatoses caused by work. Occupational allergic contact dermatitis was found in 10.9% of the workers. The estimated frequency of irritant contact dermatitis caused by work was 6.1%. Dermatitis on the hands was associated with contact allergy to epoxy resin ($P=0.017$). The number of days on leave before the clinical examination was negatively associated with the presence of dermatitis ($P=0.001$). Among workers employed 7–12 months, the frequency of occupational contact allergy was higher than that among workers employed for ≤ 6 months ($P=0.004$). Females both washed their hands more often ($P<0.001$) and used more moisturizers/protection creams at work ($P<0.001$) than males. No sex differences were found concerning dermatitis on the hands.

Key words: epoxy resin; epoxy resin system; occupational allergic contact dermatitis; occupational contact allergy; occupational dermatosis; work-related skin disease. © Blackwell Munksgaard, 2004.

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Increased production of wind turbines has taken place during recent years. Rotor blades for wind turbines are manufactured from fibre-reinforced plastics. When the manufacture of rotor blades for wind turbines in a Danish factory was changed from a process based on polyester to a process based on epoxy resin system(s) (ERSs), a cluster of cases of work-related dermatitis appeared (1). An investigation, which included questionnaires, interviews, clinical examinations and patch testing with the European standard patch-test series as well as a specially profiled occupational patch-test series (OS), was initiated. The frequencies of work-related dermatoses such as occupational allergic contact dermatitis, irritant contact dermatitis caused by work and skin disease aggravated by work were estimated. Additionally, the large number of employees investigated and a blinded study design enabled analyses of statistical associations between clinical findings and occupational contact allergy, employment time and other parameters. The overall intention was to gain knowledge as a basis for improvement

of the diagnostics and prevention of occupational skin disease. The present article deals with the occupational dermatoses found at the investigated factory. Detailed results concerning the specific work-related contact allergies are published separately (2).

Materials and Methods

The plant

Blade shells as well as beams and assembly fittings for the blades were manufactured by a process based on ERS. The rotor blades were constructed with an outer coating of liquid ERS with an epoxy resin based on trimethylolpropane triglycidylether and several inner layers of glass fibre preimpregnated with ERS (prepreg). The beams and the assembly fittings were also constructed from a similar type of prepreg. The epoxy resin used for the prepreg was based on diglycidyl ether of bisphenol A (DGEBA-R). Both coating and prepreg were hardened at high temperature. The moulds for manufacturing the

blades were constructed from glass fibre sheets impregnated at the plant with a liquid ERS with an epoxy resin based on tetraglycidyl-4,4'-methylene dianiline. The production of the rotor blades was divided into units for cutting prepreg, constructing blade shells, beams or assembly fittings and a finishing unit. The work schedule for most workers was 3 days of work, 1 day on leave, 3 days of work and 6 days on leave, with 12-h shifts.

General plan of investigation

The investigation was a field study performed on location. It was designed to include all employees in a consultation, consisting of an interview performed by an occupational physician, immediately followed by a clinical examination performed by an occupational dermatologist. Based on the findings at the consultation, it was decided whether the worker had a suspected occupational skin disease or not. Further investigation by patch testing with the OS and the European standard patch-test series was offered to those with suspected occupational skin disease. The design of the study supplemented with the number of participants is shown in Fig. 1. On the occasions when the readings of the patch tests were performed by the occupational dermatologist, an occupational physician saw the employees with OCA for further information and advice. The study was approved by the Danish Scientific Research Ethics Committee. Informed consent was obtained from each worker.

Statistical analysis

Data were recorded in and analysed with the SPSS for Windows (release 11.0, SPSS Inc., Chicago, IL, USA). When no statistical test is given for the

P value, Fisher's exact test was used. The Mann-Whitney *U*-test was used for comparing mean ranks between 2 independent groups.

Study population

The investigation took place in January 2001, and the number of workers employed was then 843. The majority (119) of those failing to take part in the study attended an introductory course for new employees. 63/724 (8.7%) did not wish to take part in the study, leaving 661 potential participants. 69 were on sick leave, but some of them returned during the study and were included. In all 603/724 (83.3%), workers were interviewed and clinically examined [511 (84.7%) males and 92 (15.3%) females]. Although indication was found, 54/603 (9.0%) of the workers were not patch tested. There were no statistically significant differences concerning age, sex or employment time between the patch-tested workers and the 54 workers with indication but not patch tested. The causes for being on sick leave among the absent employees were not possible to obtain. The number of workers who had left their employment after epoxy-based production had started and their reason for leaving was also not possible to obtain.

The mean age among the examined workers was 37.6 years (range 18–64), with no significant differences between the males and females.

The construction of the blades or moulds engaged 57.5% of the workers investigated, 20.9% being engaged in the finishing unit. The remaining 21.6% of the workers were engaged in repair, maintenance and storage. In the finishing unit, the workers were exposed to dust from grinding of both the coating and the prepreg. All workers were, or had been to various degrees, exposed to components of

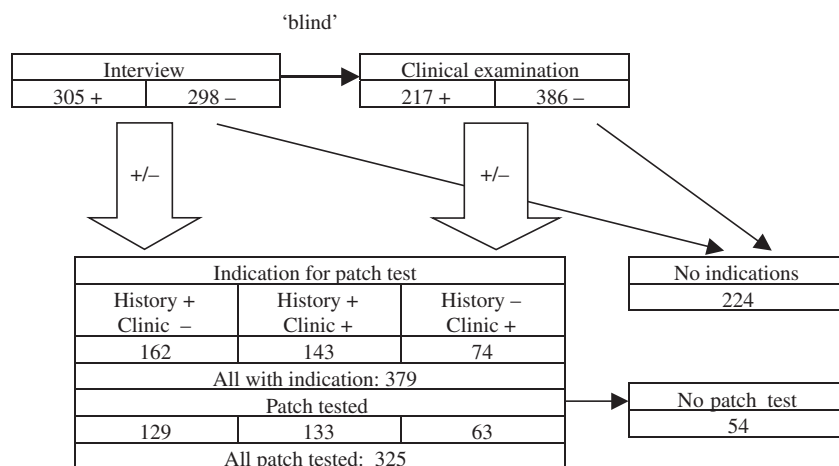


Fig. 1. The design of the study ($n = 603$). Within each group, the number of individuals based on indications for patch testing is given. Whether indications for patch testing was found or not is indicated by + or -.

several types of ERS, including DGEBA-R. Based on information obtained by visits to the plant, it was concluded that exposure to sensitizers and irritants was such that, in the majority of workers, those parts of the hands and forearms generally considered to first acquire signs of dermatitis, due to exogenous factors (3), would primarily be affected.

Interviews and clinical examination

The interview was based on questionnaires used earlier by our department in similar industrial investigations (4–7). It contained questions concerning present and previous skin problems, their location, atopic diathesis (defined as a history of at least 1 of the criteria asthma, rhinoconjunctivitis and childhood eczema), sick-leave periods, skin protection, the unit in which the skin problems first started, etc. The criteria for patch testing based on history were ongoing skin disease and/or skin disease present at any time after employment at the wind turbine factory. The clinical examination was performed by the dermatologist immediately after the interview and without the knowledge of the results of the interview or any information obtained from the worker. Hands, forearms, face and neck were examined for signs of dermatitis. Dryness, 'chapping', redness, infiltration, papules, vesicles and hyperkeratosis were recorded. The criteria for patch testing based on clinical findings

of signs of dermatitis were the presence of redness and infiltration and/or papules and/or vesicles. The area affected within the locations investigated was also noted.

Patch testing

The OS contained ingredients and products used at the investigated factory in ERS, polyurethane glues and other work material as well as products used for care and protection. DGEBA-R was patch tested as part of the European standard patch-test series. Furthermore, as part of the OS, an epoxy resin based on diglycidyl ether of bisphenol F, an epoxy novolac resin, epoxy resins based on trimethylolpropane triglycidylether, tetraglycidyl-4,4'-methylene dianiline and cycloaliphatic epoxy resin, respectively, were patch tested. Reactive diluents, i.e. 1,4-butanediol diglycidyl ether, 1,6-hexanediol diglycidyl ether and phenyl glycidyl ether, were also part of the OS. Several amine hardeners and their components, when obtainable, were patch tested. Further details of the OS are published separately (2).

Work-related skin disease

Based on traditional criteria (3, 8), the following procedure was used to assess the relationship of skin diseases to work (Fig. 2). In the present

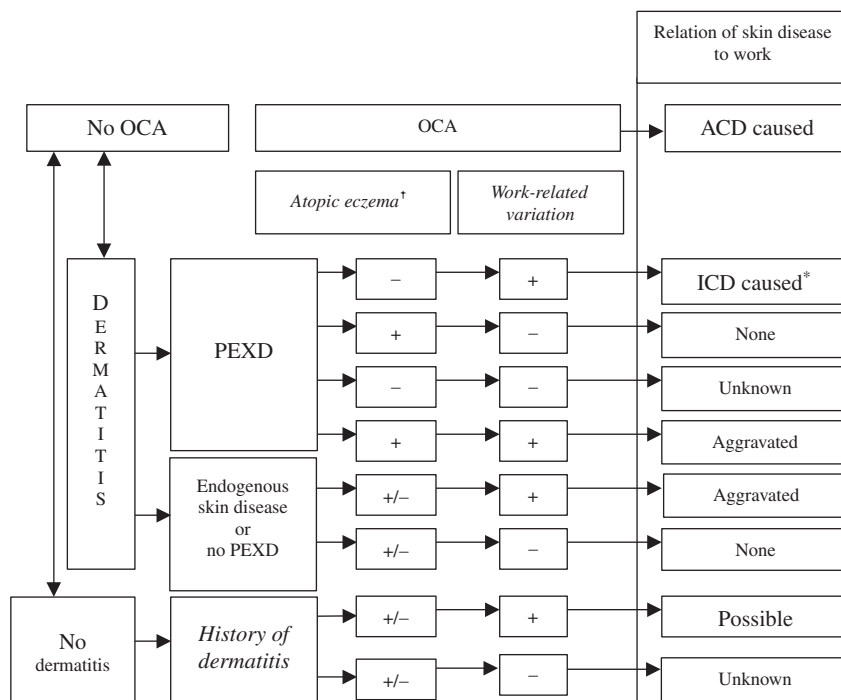


Fig. 2. Assessment of relations between skin disease and work based on clinical findings, interviews and patch testing with work material. ACD, allergic contact dermatitis; ICD, irritant contact dermatitis; OCA, occupational contact allergy; PEXD, possible exogenous contact dermatitis. Criteria based on anamnestic information are in italics. *Additional criterion: onset in the present employment. [†]Defined as a history of childhood eczema.

study, OCA was defined as contact allergy to at least 1 test preparation in the OS and/or DGEBA-R in the European standard test series. Independent of inclusion criteria and history of earlier skin disease, OCA was considered to be ACD caused by work. Besides occupational ACD, the assessment of the relationship between skin disease and work was based mainly on clinical findings of ongoing dermatitis at the time of the investigation. To identify possible exogenous dermatitis (PEXD) on hands and forearms, workers with signs of dermatitis on the dorsal and/or interstitial (and not volar) aspects of the hands (7) and/or volar (and not dorsal) aspects of the forearms were grouped. The PEXD group was used primarily to identify workers with clinical findings consistent with possible ICD. Further identification of the relationship between skin disease and work was based on the combination of known exposure to irritants, clinical findings and information obtained in the interview. Childhood eczema was used as a criterion for atopic eczema (9).

(i) The criteria for ICD caused by work were PEXD, no endogenous skin disease, a history of onset in the present work and varying intensity in relation to work. (ii) Skin disease aggravated by work was considered in workers with PEXD and childhood eczema, or clinically diagnosed endogenous skin disease, and a history of work-related aggravation. (iii) Workers with an endogenous skin disease without a history of work-related variation were considered to have no relation between skin disease and work. (iv) Workers with PEXD without a history of variation in relation to work were assigned with an unknown relation between work and skin disease. A similar procedure, as described for hands and forearms, was used for clinical findings of the face. Although several types of relationship between skin disease and work may coexist in the same patient, each worker was assigned only with 1 type of relationship between skin disease and work.

In addition to the workers with OCA and/or ongoing dermatitis, a group of workers without dermatitis at the clinical examination, but with a history of signs and symptoms related to eczema on examined locations and work-related variation, was identified as having possibly work-related skin disease.

Regardless of additional findings, the group with PEXD of the hands was also used for the investigation of associations between clinical findings and known or suspected exogenous factors.

Results

Criteria for patch testing

The number of patch-tested workers within the groups of indications is given in Fig. 1. Indications for patch testing were found in 379/603 (62.9%) of the workers investigated and 325/603 (53.9%) were patch tested, i.e. 85.8% of the workers with indication(s). Within the group of workers who fulfilled criteria based both on history and clinical findings, 93.0% were patch tested.

Sex differences are given in Fig. 3. A slightly higher proportion of females than males were patch tested (58/92, 63.0%, compared to 267/511, 52.3%, $P = 0.069$). Regardless of simultaneous clinical findings, statistically significantly more females (58/92, 63.0%) than males (247/511, 48.3%) fulfilled criteria for patch testing based on history ($P = 0.012$). There was no statistically significant difference between males and females concerning all clinical indications ($P > 0.3$). The mean and median employment time was 34.5 (range 1–210) months and 24.0 months, respectively, with no significant differences between males and females or between the patch-tested workers and the workers who were not patch tested.

History and clinical findings

Childhood eczema was reported by 53/603 (8.8%, 7.6% males and 15.2% females, $P = 0.026$). The frequency of atopic diathesis was estimated to be 153/603 (25.4%), and there was no significant difference between the sexes. The hands were the most common location of reported skin complaints (145/603, 24.0%). No association between a history of eczema as a child and reported skin complaints on the hands was found ($P > 0.3$). The skin complaint started during the working week according to 216/603 (35.8%) of the workers. The finishing unit was most commonly reported as the unit where skin complaints had started (81 workers), followed by the blade shell unit and the prepreg cutting unit (53 and 50 workers, respectively).

Protection cream and/or moisturizing cream was used at work by 41.5% of the workers, and 95.5% used gloves at work. Significantly more females than males (56/91, 61.5% and 194/510, 38.0%, respectively, $P < 0.001$) (Fig. 3) used creams at work. Females washed their hands more often than did males ($P < 0.001$) (Mann–Whitney) (Fig. 3). There was no difference between males and females concerning use of gloves at home, but more females than males used creams at home ($P < 0.001$).

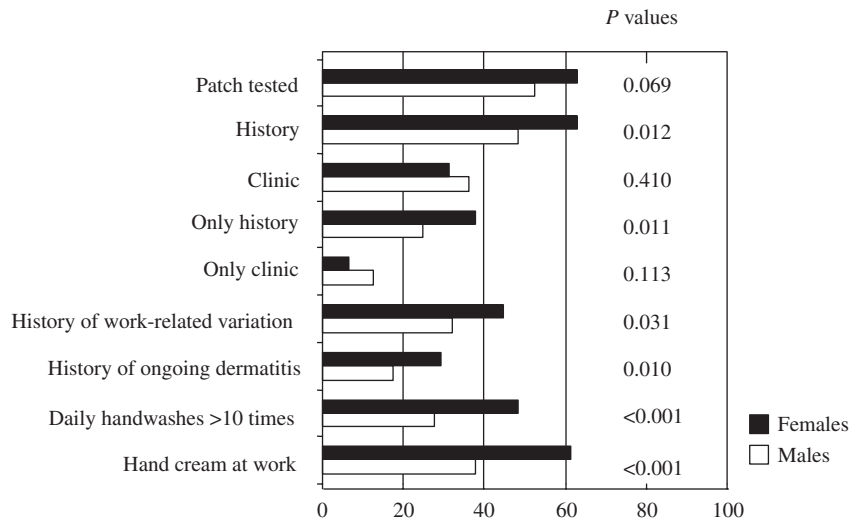


Fig. 3. Sex differences ($n = 603$, 511 males and 92 females). History, all anamnestic indications for patch testing. Clinic, all clinical indications for patch testing. Proportions within the sexes are shown as well as P values for comparisons between the sexes.

On clinical examination, the hands were found to be the predominant location of dermatitis. 23 employees had vesicles and/or hyperkeratosis of the palmar aspect of the hands. 21 employees had clear or suspected seborrheic dermatitis of the face. 10 workers had psoriasis, and 1 worker had lichen ruber. Further 2 cases of dermatological diagnoses without relation to work were found. Mycosis of the hands was suspected in 2 further cases. In some cases, it was impossible to settle for a specific clinical diagnosis due to the blinded design of the study.

Atopic diathesis was found in 64/214 (29.9%) fulfilling clinical criteria for patch testing and 89/389 (22.9%) without clinical indication for patch testing ($P = 0.063$). No association was found between a history of childhood eczema and indication for patch testing based on clinical findings ($P = 0.230$). PEXD of the hands was found in 100 (30.8%) of the patch-tested workers. As for all clinical findings, there were no significant sex differences. No associations between PEXD on the hands or any clinical findings on the dorsal aspects of the hands and the number of reported hand washes per day ($P > 0.3$, Mann–Whitney) or use of moisturizers/protection creams ($P > 0.3$) at work were found. There were no significant associations within the sexes between these clinical findings and hand washes or cream use.

Work-related skin disease

The frequencies of work-related dermatitis are summarized in Table 1. Dermatitis either caused or aggravated by work was found in 134 (41.2%) of the patch-tested workers.

Dermatitis caused by work was diagnosed in 103 (31.7%) patch-tested workers, and occupational ACD was found in 66 (20.3%) patch-tested workers. Contact allergy to DGEBA-R was found in 34 patch-tested workers (10.5%), corresponding to 5.6% among all the workers investigated. Detailed information on the patch-test results found within the present study is published separately (2). ICD caused by work was estimated to be present in 37 (11.4%) of the patch-tested workers. Skin diseases aggravated by work were found in 31 (9.5%) workers. Possibly work-related skin disease was found in 39 (12.0%) workers without ongoing dermatitis.

Work-related variation of dermatitis. Workers without any clinical indication for patch testing had been away from work for more days compared to workers who were found to have clinical indication for patch testing (mean 1.8 days, range 0–36 and mean 1.0 days, range 0–8, respectively, $P = 0.001$, Mann–Whitney).

Employment time and OCA. The number of patch-tested workers and the frequency of OCA in relation to employment time are shown in Fig. 4. The proportion of OCA in relation to employment time calculated on all employees is shown in Fig. 5. There was no clear statistical association between employment time and OCA either calculated on all patch-tested workers or on all investigated workers ($P = 0.193$ and 0.139 , respectively, Mann–Whitney). However, if OCA among workers employed ≤ 6 months was compared to that among workers employed for 7–12 months, there was a statistically significant higher frequency of

Table 1. Relationships between skin disease and work among 325 patch-tested workers (267 males and 58 females) and when calculated on all 603 (511 males and 92 females) investigated workers

	Number	Patch tested (%)			All (%)		
		Tot	M	F	Tot	M	F
Work related	134	41.2	42.3	36.2	22.2	22.1	22.8
Caused	103	31.7	31.5	32.6	17.1	16.4	20.7
ACD	66	20.3	19.9	22.4	10.9	10.4	14.1
ICD	37	11.4	11.6	10.3	6.1	6.1	6.5
Aggravated	31	9.5	10.9	3.4	5.1	5.7	2.2
Possible work-related skin disease ^a	39	12.0	11.6	13.8	6.5	6.1	8.7
Unknown	120	36.9	36.7	37.9	19.9	19.2	23.9
With dermatitis	51	15.7	17.6	6.9	8.5	9.2	4.3
Without dermatitis	69	21.2	19.1	31.0	11.4	10.0	19.6
No relation	32	9.8	9.4	12.1	5.3	4.9	7.6

ACD = allergic contact dermatitis; F = proportion within females; ICD = irritant contact dermatitis; M = proportion within males.

^aBased exclusively on history.

OCA within the latter group when calculated on all investigated workers (4/117, 3.4% compared to 11/67, 16.4%, $P=0.004$) (Fig. 5). The number of patch-tested workers also differed between the 2 groups. Among workers employed for ≤ 6 months, 51/117 (43.6%) were patch tested compared to 43/67 (64.2%) among workers employed for 7–12 months ($P=0.009$) (Fig. 6). There was also an association for OCA if the comparison between the 2 groups of newly employed is calculated on the patch-tested workers (4/51, 7.8% compared to 11/43, 25.6%, $P=0.025$) (Fig. 6). There were statistically significant differences between these 2 groups of employees concerning criteria for patch testing based on history (38/117, 32.5% versus 38/67, 56.7%, $P=0.002$) and also concerning PEXD on the hands (23/117, 19.7% versus 26/67, 38.8%, $P=0.006$) (Fig. 6).

Dermatitis and OCA. Contact allergy to DGEBA-R was found in 17/100 (17.0%) workers with PEXD on the hands (regardless of simultaneous endogenous skin disease) and in 17/225 (7.6%) without PEXD on the hands ($P=0.017$). Contact allergy to DGEBA-R was also associated with clinical findings on the dorsal aspects of the hands, including dryness (23/143, 16.1% compared to 11/182, 6.0%, $P=0.006$). No statistical associations were found when comparisons with the clinical findings of the hands were made separately with all OCA, with amines or with contact allergy to at least 1 substance in European standard test series (DGEBA-R excluded). There was no statistical association between clinical findings on the face and any of the above-mentioned contact allergies. No association was found between childhood eczema or atopic diathesis and OCA.

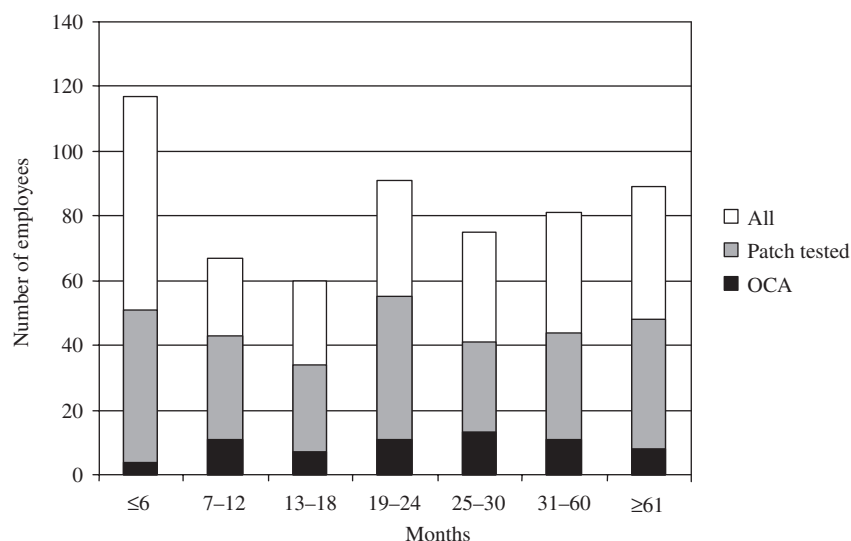


Fig. 4. Employment time, number of patch-tested workers and occupational contact allergy (OCA) ($n=580$). 23 workers did not give information concerning their employment time, 9/23 were patch tested and 1/23 had OCA.

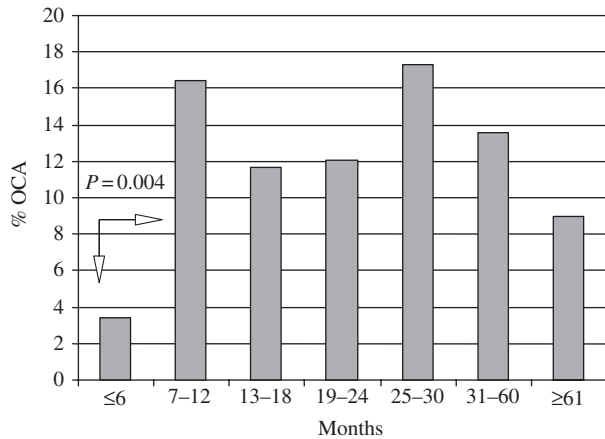


Fig. 5. Employment time and occupational contact allergy (OCA) ($n=580$). 23 workers did not give information concerning their employment time, 9/23 were patch tested and 1/23 had OCA. The P value for the comparison between the first and second half year of employment is given.

Morbidity and OCA. Among the 325 patch-tested workers, 100 (30.8%) had previously seen a doctor concerning their skin symptoms. 34/66 (51.5%) of these 100 workers were found to have OCA and 66/259 (25.5%) did not have OCA. ($P < 0.001$). Previous patch tests were reported by 65 (10.8%) workers. 55 workers without a history of previous patch test and contact allergy to epoxy resin and/or hardener were found to have OCA in this study. Among these 55 workers with presently diagnosed OCA, 23 (41.8%) had previously seen a doctor concerning their skin symptoms and 77/270 (28.5%) without presently diagnosed OCA ($P = 0.056$) had also seen a doctor for the same reason. Contact allergy to

DGEBA-R was found in 12 of the 23 workers who had previously seen a doctor.

Among the patch-tested workers, 35 (10.8%) had been on sick leave because of their skin symptoms. 13/66 (19.7%) of the workers with OCA and 22/259 (8.5%) without OCA had been on sick leave because of skin disease ($P = 0.014$). Among workers with OCA primarily diagnosed within the present study, 8/35 (22.9%) had been on sick leave and 47/290 (16.2%) had not been on sick leave ($P > 0.3$).

Of the 100 workers who had seen a doctor concerning skin symptoms, 10/49 (20.4%) were found to have contact allergy only to the European standard test series (DGEBA-R excluded) and 90/276 (32.6%) did not have any such contact allergy ($P = 0.095$). Thus, it was more common to have consulted a doctor concerning skin complaints among those without contact allergy exclusively to the European standard test series (DGEBA-R excluded).

Skin care and OCA. Within the group of patch-tested workers, there was a statistically significantly higher proportion of workers who used protection creams/moisturizers at work among workers with OCA (36/66, 54.5%) compared to those without OCA (101/258, 39.5%, $P = 0.026$, 1 female did not respond to the question concerning cream usage). There were no significant associations between the number of daily hand washes at work and OCA.

Interviews versus clinical findings

Among all investigated workers, 466/603 (77.3%) did not report any ongoing skin complaints, yet 125/466 (26.8%) were found to fulfill clinical criteria for patch testing. There was no difference between males and females (110/406, 27.1% and 15/60, 25%, respectively) (Fig. 7). Among workers without clinical indication for patch testing, 22/323 (6.8%) males and 16/63 (25.4%) females reported ongoing skin disease on clinically examined locations but were not found to have dermatitis on clinical examination ($P < 0.001$) (Fig. 7). The overall statistical association between a history of ongoing skin disease on examined locations and clinical indication for patch testing was high ($P < 0.001$).

Discussion

The aim of the present study was to estimate frequencies of work-related skin diseases as well as associations between clinical findings and selected factors with known or suspected relation to work. The aim was not to find the exact

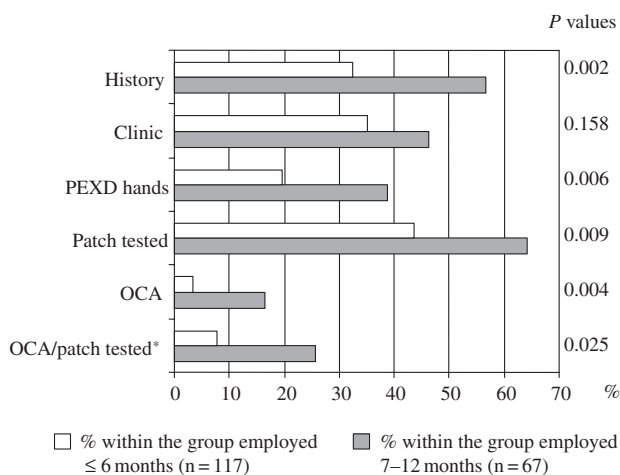


Fig. 6. Workers employed ≤ 12 months. History, all anamnestic indication for patch testing. Clinic, all clinical indication for patch testing. OCA, occupational contact allergy; PEXD, possible exogenous contact dermatitis. P values are given for the comparisons. * ≤ 6 months, $n = 51$ and 7–12 months, $n = 43$.

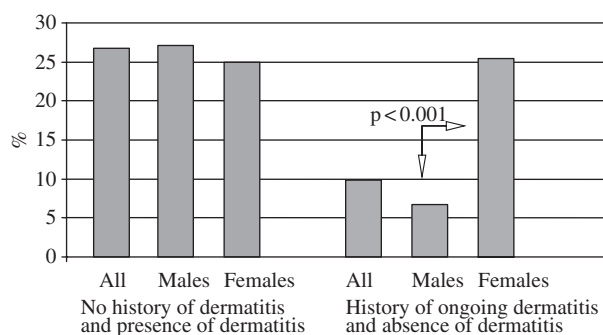


Fig. 7. Sex differences with regard to the presence of dermatitis among 466 workers (406 males and 60 females) without history of dermatitis and with regard to absence of dermatitis among 386 workers (323 males and 63 females) with a history of ongoing dermatitis on investigated locations.

numbers of work-related skin diseases but rather magnitudes as a basis for preventive measures. Cases within the group of ICD caused by work presented here include persons with a history of onset at this factory, with work-related variation and with dermatitis on specified locations of the hands and/or forearms. These criteria may possibly lead to underdiagnosis of ICD, including glass fibre dermatitis. Due to the fluctuation of dermatitis, it would have been necessary to follow workers with unknown relation between ongoing dermatitis and work over time as well as those with possible work-related skin disease without dermatitis, to obtain a more accurate diagnosis. Workers with indication for patch testing based exclusively on clinical findings (and without OCA) clearly had no history of work-related variation, and therefore, the relationship to work concerning their dermatitis was impossible to assess within the design of the present study. It has been argued that, if a questionnaire is used for screening, individuals with indications of the mildest symptoms of possible hand dermatitis should be included in the medical examination (10). The same reasoning should be applied to clinical findings in relation to patch testing with work material.

Some degree of healthy worker selection can be anticipated, as the reasons for being on sick leave or having left work were unknown. Among the workers found to fulfill the criteria for patch testing, 54 (14.4%) did not want to continue the investigation. These circumstances entail that the frequencies of work-related skin diseases found in the present study represent a minimum.

Occupational skin disease

This study was performed in January (2001) on the windy western coast of Denmark. Many indi-

viduals also had leisure activities which included exposure to possible irritants. Thus, it might be suspected that factors other than work could have contributed significantly to the dermatological findings. Still, the clinical findings of dermatitis varied significantly depending on whether the employee was at work at the time of the investigation or had been on leave recently, demonstrating the importance of occupational exposure to allergens and irritants for the skin disease.

According to the results of our study, contact allergy to DGEBA-R was statistically associated with PEXD of the hands and also all clinical findings (including dryness) on the dorsal aspect of the hands. The results support the importance of contact allergy to DGEBA-R at the investigated factory for the presence of dermatitis. The clinical importance of OCA is also supported by the association of OCA with both seeing a doctor and being on sick leave due to skin disease.

Another important finding is the increased number of cases with OCA occurring during the first year of employment. The frequency of OCA could, theoretically, have continued to increase at the same rate as during the first year, leading to an accumulation of OCA over time. It is unknown to the investigators how many individuals had terminated their employment due to skin disease, but according to oral information, very few with previously diagnosed OCA had left their employment. It is also possible that, with the present exposure to occupational allergens, the number of individuals with OCA could remain approximately at the same level after the first year of employment.

In this study, the frequency of occupational ACD (20.3%) among patch-tested workers was higher than that with occupational ICD (11.4%). This is in agreement with a recent survey performed by Kucenic et al. (11) and also with previous findings (12). There are also studies in which occupational ICD predominates (13, 14). The clinical morphology of the dermatitis caused by contact allergy and irritant substances does not clearly differ. Furthermore, sensitizers and irritants are often present simultaneously in the work environment. Patch testing with work environment material and substances must be performed, and relevance of patch-test reactions must be assessed to evaluate the frequencies of ICD and ACD. Naturally, the relative importance of ACD and ICD also differs depending on whether the process involves the presence of sensitizers, irritants and wet work. At the investigated factory, there were a large number of different known contact sensitizers and/or irritants present, such as components of ERS, grinding

dust and frequent hand washing. If the legal definition of wet work now used in Germany were applied to this factory, the use of gloves alone would classify the work as a wet work (15). Varying frequencies of occupational dermatoses are reported from different industries, ranging from 16.1% to 40.4% (4–6, 16), when calculated on all workers in the industries in question. In this study, the corresponding frequency was 17.1%. Due to factors already mentioned and also the possibility of missed occupational contact allergens in the OS, this figure represents a minimum.

Interviews and clinical findings

For practical reasons, more than 1 occupational physician and more than 1 dermatologist performed the investigation. First, the workers were interviewed and immediately thereafter clinically examined. The interview was structured according to a questionnaire, in which the questions were answered in dialogue with an occupational physician. Questions concerning validity of questionnaires are therefore partly beyond the scope of the present study. Still, there are interesting discrepancies between information given in the interview and the results of the clinical examination.

In earlier studies, it has been found that self-reported hand eczema may be underestimated by questionnaires. Frequencies ranging from 7.7% to 28% of hand eczema and/or skin disease have been reported among clinically investigated no-responders (5, 17–19). In the present study, the corresponding frequency was 26.8%.

Discrepancies between female and male anamnestic information compared to the results of the dermatological examination were found in this study. Among females, the frequency of reported ongoing skin disease on examined locations without clinical findings was high. The reason(s) for the discrepancy between the dermatologist's evaluation and the females' own opinion is unknown. It could be due to the greater use of creams among females, but data available within this study does not support that. Another possibility is differences in understanding of signs of skin disease. Females report a higher frequency of hand washes, and they more often use creams at work; still, they have approximately the same frequency of PEXD of the hands as males. Possibly they treat the irritant effects of frequent hand washes, while not getting rid of signs of dermatitis caused by contact allergy.

The results presented within this study point at several interrelated circumstances that may contribute to the presence of clinical findings and

should therefore be subjected to more studies, specially designed to elucidate these issues. Further statistical analysis of this material will be published elsewhere.

The most important risk factor of acquiring contact allergy is the dose of the allergen per unit of skin area and the time the allergen remains on the skin. Sensitization may thus occur on a single occasion if, for instance, the product is accidentally spilled on the skin. In the prepreg-cutting unit and other units where uncured prepreg was used, fibres with DGEBA-R may increase the risk of acquiring contact allergy due to penetration of fragments of fibres into the skin. In the finishing unit, the work was more of a handicraft type. The work included curing, possibly at lower temperature, of repaired segments of the blades. The blades were ground, which produced dust which thus contained irritants such as glass fibre and possibly allergens such as uncured epoxy resins.

The use of protective gloves was mandatory, and 3 layers of gloves were recommended. From inside outward, cotton gloves, thin nitrile rubber gloves and thick black rubber gloves were most often used. The gloves were discarded when removed. However, there is always a risk of contamination by the outside of the gloves on the skin and also of contamination of other personal preventive equipment such as protective masks. The performance of the gloves in the actual work situation is difficult to evaluate. *In vivo* studies of the penetration of acrylates through different types of protective gloves have shown that some gloves give very poor protection (20, 21). Corresponding studies of the penetration of epoxy resins have not, to the knowledge of the authors, been published.

It is important to strive for increased automation of the production process, and such an effort has been made at this factory and is continuously being worked at. The investigated factory has also developed into a plant where new products and prototypes are constructed, which means that it was difficult fully to automate the production process.

Conclusion

The association found between clinical findings on the hands and contact allergy to DGEBA-R shows the clinical importance of OCA. A time-related fluctuation of dermatitis in relation to work was also found, as well as a high rate of sensitization to occupational allergens during the first year of employment. Thorough education concerning protection, most importantly among

new employees, as well as production methods that minimize exposure, especially to the well-known occupational sensitizer DGEBA-R, are necessary measures for preventing occupational dermatoses in epoxy-based production of wind turbine rotor blades.

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Address:

Ann Pontén
Malmö University Hospital
Department of Occupational and Environmental Dermatology
S-205 02 Malmö
Sweden
Tel: +46 40 337833
Fax: +46 40 336213
e-mail: ann.ponten@skane.se