

Cement-Induced Chromate Occupational Allergic Contact Dermatitis

Khalaf Kridin, MD,* Reuven Bergman, MD,* Mogher Khamaisi, MD, PhD,† Shira Zelber-Sagi, PhD,‡ and Sara Weltfriend, MD*

Background: Hexavalent chromium in cement is a common cause of occupational allergic contact dermatitis (OACD).

Methods: Analysis of patch test data during 1999 to 2013 was done. Patients with cement-induced chromate OACD filled the Dermatology Life Quality Index, graded 1 to 5.

Results: Of 4846 consecutive patients who were patch tested, 146 (3%) were chromate-sensitive. Of 46 (31.5%) who presented with chromate OACD, 27 (59%) had cement-induced chromate OACD. The proportion of chromate-sensitive patients with clinically relevant cement exposure increased from 7.7% in 2002 to 2004 to 28.7% in 2011 to 2013 ($P=0.04$). The median age of presentation was younger than for other chromate-sensitive patients (32 vs 42 years). Hand eczema (88.9%) was the most frequent clinical presentation. Of the 27 with cement-induced chromate OACD, 21 (77.8%) had ongoing dermatitis at the time of the review. Although 14/27 (51.9%) changed their occupation to avoid exposure to cement, symptoms persisted in 9/14 (64.3%). Prolonged exposure to cement before development of symptoms was associated with chronicity. All the symptomatic patients experienced at least a moderate effect on their quality of life (grade 3 or higher on the Dermatology Life Quality Index).

Conclusions: We recommend the adoption of the European legislation in Israel, to reduce the prevalence of chromate OACD from cement.

Occupational exposure to cement is a major risk factor for the development of chromate allergy. Hexavalent chromium (chromium VI) in cement is a common cause of allergic contact dermatitis (ACD).¹

The prevalence of ACD due to chromate among construction workers has been reported as 10%.² In a study conducted in Germany, the prevalence of ACD among symptomatic construction workers who were patch tested was more than 45%.³ Such high prevalence contrasts sharply with the rate of about 1% in the general population, as was assessed using lymphocyte transformation test.⁴

The prognosis of cement-induced chromate occupational allergic contact dermatitis (OACD) is poor.^{5,6} Patients experience severe and disabling dermatitis, together with persistent post-occupational dermatitis, with marked economic consequences and adverse effects on quality of life (QoL).⁵

In 1950, water-soluble chromium was discovered as the cause of cement allergy.⁷ Chromium is converted from an inert,

insoluble, trivalent form to a soluble, allergenic, hexavalent form during kiln processing. The addition of ferrous sulfate to cement reduces the hexavalent form to a trivalent state (chromium III), which has a low degree of skin permeation and therefore rarely causes sensitization.⁸

During the past few decades, legislative changes in Europe have mandated the addition of ferrous sulfate to cement to reduce the concentration of and exposure to hexavalent chromium. Subsequent to these legislations, the prevalence of chromate allergy decreased markedly among patients patch tested in those countries.⁹

Despite the longstanding global awareness of cement-induced occupational chromate allergy and, in particular, the poor prognosis of this diagnosis, no studies were undertaken in Israel to estimate the national scope of the problem.

The current study aimed to describe the clinical characteristics and the prognosis of chromate-sensitive construction workers, and to estimate the magnitude of the chromate OACD problem in the construction industry in Israel.

METHODS

Study Population and Design

We analyzed the records of all patients with suspected ACD, according to patch testing performed from January 1, 1999, to December 31, 2013, at the Patch Test Clinic, Rambam Medical Center, Haifa, Israel. The study had approval from the institutional Ethics Committee of our medical center. For patients who were

From the *Department of Dermatology, and †Institute of Endocrinology, Diabetes and Metabolism and Internal Medicine D, Rambam Medical Center and RB Rappaport Faculty of Medicine, Technion; and ‡School of Public Health, Faculty of Social Welfare and Health Sciences, University of Haifa, Haifa, Israel.

Address reprint requests to Khalaf Kridin, MD, Department of Dermatology Rambam Medical Center, Haifa, Israel. E-mail: dr_kridin@hotmail.com.

The authors have no funding or conflicts of interest to declare.

DOI: 10.1097/DER.0000000000000203

© 2016 American Contact Dermatitis Society. All Rights Reserved.

patch tested on more than one occasion during the test period, the first result was used for the analysis.

Data were stratified according to date of test, sex, and age. Information according to the MOAHLFA (males, occupational dermatitis, atopic background, hand dermatitis, leg dermatitis, facial dermatitis, age older than 40 years) index was recorded.

The medical records of patients with chromate allergy attributed to exposure to cement were analyzed thoroughly. The information accessed was compared between patients with cement-induced chromate ACD and those with other chromate-sensitive ACD.

The relevance of positive allergens was recorded as probable, possible, past, unknown, or not relevant. For the purpose of this study, current relevance was defined as present relevance (probable or possible), unless otherwise stated. Relevance was assessed as probable if the substance identified by patch testing could be verified as present in the known skin contactants of the patient. Relevance was defined possible if the patient was exposed to circumstances in which skin contact with materials known to contain the putative allergen would likely occur. An atopic predisposition was defined as having at least one of the atopic markers (a history of atopic dermatitis, asthma, or allergic rhinitis).

Prospective Data Collection

Those who were reached, and who agreed, filled the Dermatology Life Quality Index (DLQI) questionnaire and responded to questions about the symptoms they experienced over the years. The DLQI is a self-administered, easy, and user-friendly questionnaire that assesses patient impairment attributed to the development of dermatological diseases.¹⁰ The DLQI consists of 10 questions regarding patients' perceptions of the impact of their skin diseases on various aspects of their QoL over the preceding week. This questionnaire has been validated for dermatology patients aged 16 years and older. The items of the DLQI encompass aspects such as symptoms and feelings, daily activities, leisure, work or school, personal relationships and the adverse effects of treatment. Each item is scored on a 4-point Likert scale, according to relevance to the patient: 0, not at all; 1, a little; 2, much; and 3, very much. Scores of individual items (0–3) are added to yield a total score (0–30); the higher the score, the more the QoL is impaired. Grade 1 (0–1) means no effect at all on the patient's life; grade 2 (2–5) means a small effect; grade 3 (6–10) a moderate effect; grade 4 (11–20) a very large effect, and grade 5 (21–30) an extremely large effect on the patient's life.¹⁰

The proportion of the population of Haifa and the northern districts of Israel relative to the entire population of Israel was determined from the 2006 census data.¹¹ From this, the number of cement-induced OACD in the whole country was estimated.

Patch Testing

Patch testing was performed with the European baseline series. The allergens were supplied by Chemotechnique Diagnostics

(Malmö, Sweden). All tests were applied with Finn Chambers on Scanpor tape. The patch tests were applied to the upper back and were occluded for 48 hours, and readings were performed on day 2 and day 4. Chromate allergy was assessed by testing with potassium dichromate at a dilution of 0.5% in petrolatum. The reactions were scored as [–, irritant reaction (IR), ?, +, ++, +++], according to the recommendations of the International Contact Dermatitis Research Group. Negative reactions (–), IRs, and doubtful reactions (?) were registered as a negative response. One + or more on day 4 was registered as a positive response.

Statistical Analysis

Statistical analyses were performed using STATA statistical software version 13.0 for Windows (StataCorp, College Station, TX). Frequencies were estimated for categorical variables and means and SDs were calculated for continuous variables. To test differences in continuous variables between the 2 groups, the independent samples *t* test was performed. Associations between nominal variables were performed with the Pearson χ^2 test and Fisher exact test, as appropriate. A χ^2 trend test (linear-by-linear association) was performed to examine significant trends across test years. The statistical significance level was set to 5% in all analyses.

RESULTS

A total of 4846 patients with suspected ACD, 52% women and 48% men, aged 5 to 96 years were patch tested between 1999 and 2013. Of them, 146 (3%) patients patch tested positive for potassium dichromate and had a history of exposure that was considered as relevant to the presenting dermatitis. Forty-six (31.5%) of the chromate-allergic patients presented with OACD. Occupational allergic contact dermatitis was more common in men (42) than in women (4) ($P < 0.0001$). After a thorough review of patient histories, 27 (58.7%) individuals with chromate OACD caused by relevant exposure to cement were identified (Fig. 1). For 3 (6.5%) patients, the primary source of chromate exposure was determined as leather, and for another 3 (6.5%), metals. Interestingly, we found 6 (13%) patients with chromate OACD to be employed in automobile and airplane mechanics and 2 (4.3%) to be farmers. The remaining 5 patients were a dentist, a nail technician, a detergents vendor, a worker in the plastics industry, and a worker in a printing house.

Noteworthy, 11 (40.7%) of our cement-induced OACD patients had +++ reaction, 13 (48.2%) had ++, and only 3 (11.1%) had +1. Six doubtful reactions were excluded.

Development of Occupational Chromate-Induced OACD Over the Years

Cement exposure among patients who tested positive to chromate was examined for each year in the study period. A χ^2 trend test showed a significant increase during the study period, in the proportions of individuals with cement exposure, among those who tested positive to chromate; from 7.7% in 2002 to 2004 to 28.7% in 2011 to 2013 ($P = 0.04$) (Fig. 2).

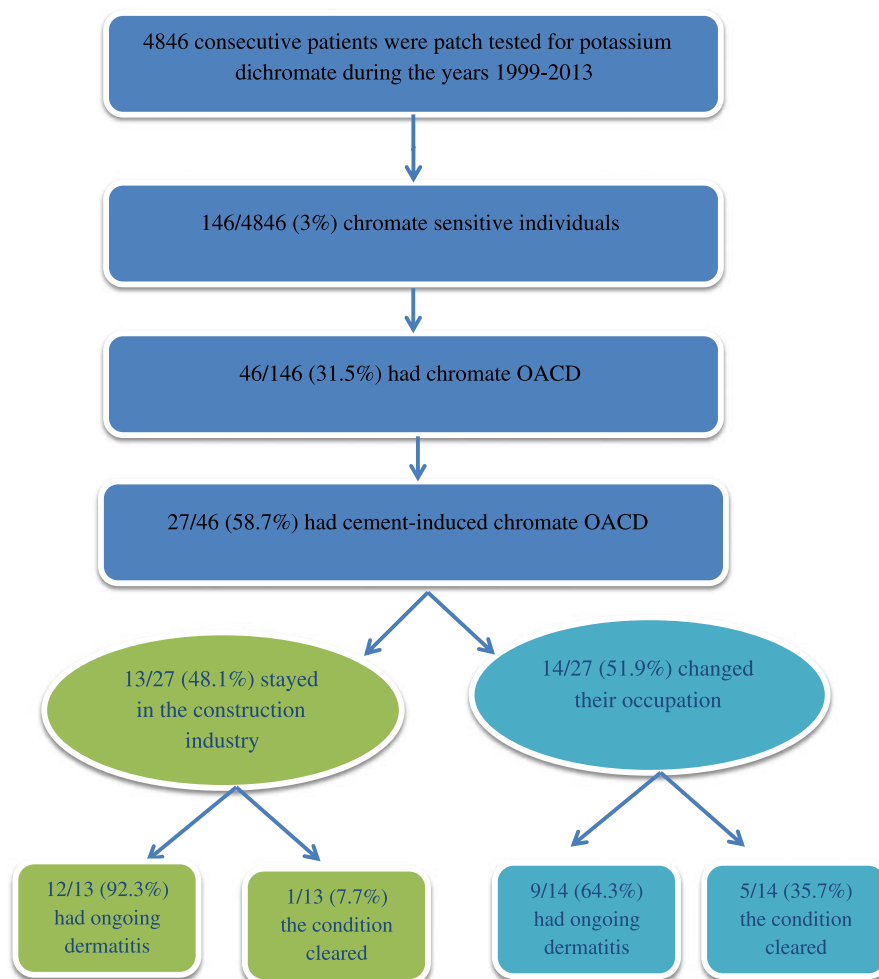


Figure 1. Flow chart summarizing the selection and outcome of cases included in the analysis.

The mean number of annual cases of cement-induced OACD was 1.8 cases. Rambam Medical Campus is the tertiary referral center for dermatology services for the entire northwest Israel. Approximately 1.567 million inhabitants live in the catchment area of the hospital. On the basis of the 2006 census, we estimate that, at an absolute minimum, 7 to 10 cases of OACD to chromium from cement occur annually in Israel.

Clinical Characteristics of Patients With OACD, Compared to Other Chromate-Allergic Patients

Table 1 presents the clinical characteristics of all 27 construction workers detected with cement-induced OACD between 1999 and 2013. The demographic and clinical characteristics of these individuals were remarkably different from the other 119 patients who tested positive for chromate. The former were all men, the median age at diagnosis of ACD was 32 years (range, 16–64 years), compared to 42 years for the other chromate-allergic patients. Sixteen (59.2%) developed OACD before age 40 years. Only 2 (7.4%) had atopic background (defined as a history of atopic dermatitis, asthma, or allergic rhinitis), which was a lower frequency than for

the other chromate-allergic patients (21.8%) ($P = 0.085$). Interestingly, 25 (92.6%) of the workers were of Arab descent, whereas only 29 (24.4%) of the other 119 chromate-sensitive patients were of this background.

Hand dermatitis (88.9%) was the most frequent clinical presentation, appearing significantly more often in construction workers than in other chromate-allergic patients (63%) ($P = 0.003$). Foot and leg dermatitis was common, and with similar frequencies among those who did and did not work in construction: 44.4% and 37.8%, respectively ($P = 0.523$). Thirteen (48.1%) of the construction workers had dermatitis in more than one location; of them, 7.4% had dermatitis of the neck, and 7.4% had universal distribution.

Coexistent Additional Allergies

Concurrent allergies to additional allergens among construction workers who tested positive for chromate were investigated. In 13 (48.1%) patients, the patch test revealed an isolated chromate allergy, 9 (33.3%) had a positive response to one additional allergen and 5 (18.5%) to 2 or more additional allergens. Dual hypersensitivity to both chromate and cobalt chloride was observed

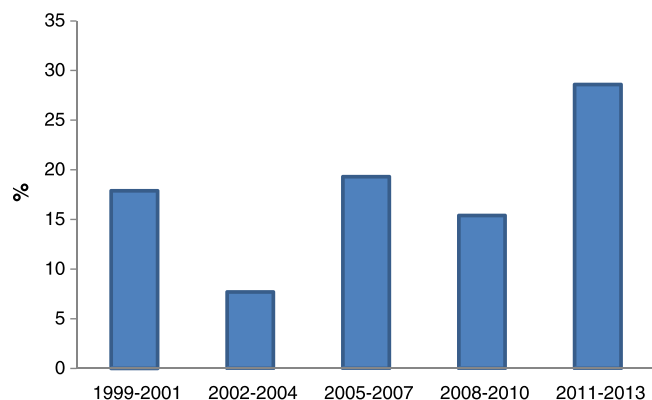


Figure 2. The proportions of individuals with cement exposure among those who tested positive for dermatitis and chromate allergy during 1999 to 2013. The increasing proportion observed between 2002 and 2011 in relevant cement exposure was statistically significant ($P = 0.02$). The columns represent 3-year periods (eg, in 1999–2001, 17.9% of patients with chromate allergy had occupational exposure to cement).

in 10 (37%), compared to 36 (30.3%) of the other 119 patients with allergy to chromate ($P = 0.49$). Combined allergy to nickel sulfate was identified in 3 (11.1%) construction workers, whereas 35 (29.4%) of the other chromate-allergic patients had such additional allergy ($P = 0.054$). In 2 (7.4%) cases, there was a coexisting allergy to Kathon CG, and 2 to a fragrance mix. The corresponding

figures in the general chromate-allergic group were 7.6% and 5.9%, respectively.

Occupational Exposure Before Cement-Induced OACD Onset and Time to Diagnosis

The mean interval between the start of occupational exposure to cement and the onset of cement-induced OACD was 10.1 years. Twelve (44.4%) were exposed to cement for 5 years or less before developing dermatitis; of them, 7 (25.9%) were exposed for less than 12 months. The occupational exposure of 15 (56.6%) exceeded 5 years. The mean duration between the onset of symptoms and diagnosis at the contact dermatitis clinic was 4.8 years. Seven (25.9%) presented within 12 months of developing symptoms. Eight (32%) workers had symptoms for more than 5 years before diagnosis.

Prognosis and QoL

The median time of follow-up was 5.2 years (range, 3–16 years). At the last follow-up, at least 3 months before the analysis, 13 (48.1%) were in the same occupation, in the construction industry. Of them, 12 (92.3%) had ongoing dermatitis and for only 1 (7.7%) worker the condition cleared despite persistent exposure (Fig. 1).

Fourteen (51.9%) patients had completely changed their type of work since initial presentation. All of them stated that they had changed their occupation due to their dermatitis. Nevertheless,

TABLE 1. Clinical Characteristics of Chromate-Sensitive Construction Workers, Compared to 119 Other Chromate Sensitive Patients

	Construction Workers (n = 27), % (n)	Other Chromate-Allergic Patients (n = 119), % (n)	P*
MOAHLFA Index			
Males	100 (27)	32.8 (39)	<0.001
Occupational dermatitis	100 (27)	15.9 (19)	<0.001
Atopic background	7.4 (2)	21.8 (26)	0.085
Hand dermatitis	88.9 (25)	63 (75)	0.003
Leg and foot dermatitis	44.4 (12)	37.8 (45)	0.520
Face dermatitis	7.4 (2)	15.9 (19)	0.366†
Age, >40 y	40.7 (11)	51.2 (61)	0.323
Additional allergens			
Cobalt chloride	37 (10)	30.3 (36)	0.493
Nickel sulfate	11.1 (3)	29.4 (35)	0.050
Kathon CG	7.4 (2)	7.6 (9)	1.000†
Fragrance	7.4 (2)	5.9 (7)	0.672†
Balsam of Peru	3.7 (1)	4.2 (5)	1.000†
Anatomical location of dermatitis‡			
Feet and legs	44.4 (12)	37.8 (45)	0.523
Face	7.4 (2)	15.9 (19)	0.366†
Universal distribution	11.1 (3)	2.5 (3)	0.077†
Hands	88.9 (25)	63 (75)	0.002
Neck	3.7 (1)	1.7 (2)	0.461

* χ^2 test.

†Fisher exact test.

‡Some patients had dermatitis in more than one anatomical location.

dermatitis persisted in 9 (64.3%) with no obvious trigger for the continuation of the eruption.

To identify predictors of chronicity, the 9 patients with persistent dermatitis, despite chromate avoidance, were compared with 5 patients in whom the dermatitis resolved after changing occupation. Patients with persistent dermatitis were exposed to cement for a longer period before the onset of symptoms (mean, 15.2 ± 10.1 years) than were those who improved (mean, 7.4 ± 9.9 years), although the difference was not statistically significant ($P = 0.1$). Moreover, patients with persistent cement-induced chromate OACD had been symptomatic for a longer duration (5.2 ± 5.8 vs 2.5 ± 2.1 years) before their chromate allergy was diagnosed and they were recommended to avoid exposure to allergen, albeit not significantly ($P = 0.4$). The mean age of onset of OACD was older among patients with persistent dermatitis (43 ± 13.2 vs 27 ± 14 years, $P = 0.06$).

Of the 27 patients who were contacted and inquired about impairment of their daily QoL due to their dermatitis, 22 filled the DLQI; of these, 20 were symptomatic. The average DLQI score for all symptomatic patients was 14 ± 6.7 . The lowest score was 6, indicating a moderate effect. Eleven (55%) experienced a very large effect and 6 (30%) an extremely large effect on their daily lives.

DISCUSSION

Occupational exposure to cement among chromate-allergic patients has increased in northern Israel during the last 15 years. In this study, all the chromate-sensitive patients with relevant exposure to cement were construction workers. Hence, we concluded that the annual number of incident cases of cement-induced chromate OACD is currently increasing in Israel.

Cement is the most cardinal substance that can cause occupational cutaneous morbidity in the construction industry. Chromate is the principal allergenic component in cement.¹² The prevalence rate of chromate allergy was found to be as high as 19.5% among construction workers, contrasting with 1% among a normal population in Switzerland in 1950.² General population rates in Denmark,¹³ the Netherlands,¹⁴ and Italy¹⁵ were as low as 0.5%. Patch testing of workers during construction of the channel tunnel revealed a prevalence rate for chromate allergy of 17%.¹⁶ In a study based on data from Northern Bavaria, the actual prevalence of chromate allergy exclusively among symptomatic workers reached 45%.³

We found that among cement-induced chromate OACD patients, the hands were the region most affected, and more so than in other chromate ACD patients (63%) ($P < 0.001$). This concurs with other reports.¹⁷ Feet and leg dermatitis was the second most common clinical picture, with similar frequency as in other chromate-allergic individuals, $P = 0.52$. Face dermatitis was detected in only 2 (7.4%) patients. Also, the study of construction workers in Northern Bavaria showed that hand dermatitis predominated, with involvement in more than 73.7% of those who presented with OACD, from 1990 to 1999.³ This contrasted with 11.6% with face dermatitis and 6.9% with leg dermatitis.

Individuals with cement-induced chromate OACD tended to present with their disease at an earlier age. This may be due to the employment of a considerable number of young men, especially Arabs, in the construction industry, exposing them to hexavalent chromium in cement during the second decade of their life. We note that Arabs constitute up to 53% of the northern region of Israel, and 25% of the Haifa district.¹¹

Combined sensitivity to both chromium and cobalt chloride were observed in 37% of the patients, a similar rate to reports from Scandinavia,¹⁸ and a much lower rate than in workers involved in the construction of the channel tunnel,¹⁹ in which 86% had such combined allergy. Both chromium and cobalt are impurities found in the clay used to make cement and, interestingly, dual sensitivity to both substances often occurs.¹⁶ Nickel sulfate is another allergen that might be present in cement. However, isolated occupationally relevant allergy to these metals from cement, without concomitant allergy to chromate, is very rare. The insoluble form of the cobalt and nickel in cement explains the very low sensitization potential.²⁰ Thus, allergy to these metals is usually secondary in the setting of damaged skin incurred upon by the existing chromate allergy; the greater the clinical severity of chromate allergy, the greater the risk of sensitization from cobalt and nickel.²⁰

Our data show poor prognosis for OACD; 64% of workers had persistent dermatitis despite their changing occupation and total avoidance of occupational exposure to cement. A Danish study of 120 individuals with chromate OACD in 1992 revealed similar results. Although 48% of that study population had completely changed their occupation to avoid chromate exposure, symptoms persisted in 69%.⁵ Most studies detecting the prognosis of OACD suggest that a change of work does not make a significant difference in prognosis.^{21–26} Fregert²² investigated a group of 555 workers, at 2 to 3 years after they were diagnosed with occupational skin disease. Of the 239 workers who had changed their job, 26.8% reported clearance of their dermatitis compared to 20.6% of workers who had not made such changes ($n = 316$). A study conducted in Canada reported that 35% of individuals who had changed work still had active dermatitis compared to 46% of those who had not changed their work ($P = 0.09$).²⁷ On the other hand, more optimistic prognosis was demonstrated among 88 Swiss construction workers with chromate OACD, who were excluded from their workplace by law and given financial support after their diagnosis, which dictated strict avoidance of occupational chromate exposure. In that study, a clearance rate of 72% was reported.²⁸

Poor prognosis can also be concluded from the great disturbances reported in QoL due to the disease; all of the symptomatic workers who answered our questionnaire experienced a medium or greater effect on their QoL, as assessed by DLQI. OCD was ranked seventh in severity on a list of 15 skin conditions; delayed pressure urticaria was listed as most severe and melanocytic nevus as least severe.²⁹ Responses of 339 patients at a patch-testing clinic modified DLQI showed that those with OCD (39%) were more likely than those with non-work-related dermatitis to report that

their skin condition interfered with sleep ($P < 0.05$), social or leisure activities ($P < 0.05$), and housekeeping ($P < 0.05$) and caused problems with their partner/friends ($P < 0.05$).³⁰

In the current study, individuals with persistent dermatitis, despite avoidance of occupational exposure to cement, had been exposed to cement for a longer period than those who improved, although this difference was not statistically significant ($P = 0.1$). Similar findings were demonstrated among OACD patients from EPIDERM²⁶; those with persistent dermatitis had been exposed to the causative agent longer than those who improved ($P = 0.09$). Furthermore, patients with persistent cement-induced chromate OACD had been symptomatic for a longer duration before their chromate allergy was diagnosed and had received advice concerning allergen avoidance ($P = 0.4$). This outcome was consistent with the study of Halbert et al⁵ who reported that being symptomatic for more than 12 months before diagnosis was a predictor of chronicity and persistent dermatitis ($P = 0.02$). The age of onset of dermatitis did not differ significantly between the groups ($P = 0.06$). We assume that the small sample size in our cohort precluded achieving statistical significance.

More cases of chromate OACD in our study (58.7%) were identified from exposure to cement as compared to leather (6.5%). This contrasts with the current situation in Europe.^{31,32} This difference is likely a consequence of the lack of legislative changes in Israel that would mandate a reduced concentration of chromium in cement to reduce exposure.

Legislative changes in Denmark in 1983 dictated the compulsory addition of ferrous sulfate to cement, reducing the amount of water-soluble chromium from approximately 10 to less than 2 ppm.³³ This resulted in a decreased rate of chromate allergy in those attending patch test clinics, from 3% in 1985 to 1986 to 1% in 1997 to 1998 ($P = 0.001$), particularly among those of working age (from 19 to 60 years). The proportion of chromate OACD also decreased, from 43% in 1985 to 1986 to 20% in 1997 to 1998.³⁴ The prevalence of chromate sensitization to cement in Denmark has since declined.^{31,35} In 1987, Finland also enforced the addition of ferrous sulfate to cement. Follow-up data from the Finnish Register of Occupational Diseases revealed that the occurrence of occupational chromate allergy subsequently decreased to less than one third of the previous level.³⁶

A high prevalence of occupational dermatitis (332 of 1138 workers; 29%) and chromate sensitization (96 of 180 workers exposed, 53%) was observed during the construction of the tunnel across the channel between England and France in 1990 to 1992.¹⁹ Likewise, German and Austrian data from 1992 to 2000 showed a high prevalence of chromate OACD among construction workers.³² The profuse information about this occupational hazard eventually led to the introduction of a European Union directive 2003/53/EC in 2005, which restricted the marketing and use of cement containing more than 2 ppm of chromium.¹⁶ Analysis of UK data since 2003 revealed a significant reduction in the incidence of chromate allergy, suggesting that the EU 2003/53/EC intervention was successful.³⁷ Such findings have been reproduced in Scandinavia,

Germany, and Austria, after legislation to reduce chromium levels in cement.^{19,32,34,36}

Before the regulation of the chromium content in cement, the rate of contact allergy to chromate was stable.^{38,39} A review of 2 occupational surveillance health schemes (EPIDERM and OPRA) between 1993 and 2004 also concluded that there had been no change in the number of chromate-related cases in the period during which legislation reducing the chromate concentration in cement was not imposed.⁴⁰

Apart from legislative changes, several strategies have been proposed to prevent chromate hypersensitivity among cement workers, including the use of protective gloves to prevent direct hand contact with cement³⁶ and the use of protective barrier cream, such as ascorbic acid cream.³²

There are several limitations to this study. First, our study provides data from a small region populated with no more than 2 million inhabitants. Second, although we had a long period of follow-up and patch-tested a large number of patients, our study cohort consists of a relatively small number of individuals diagnosed with cement-induced chromate OACD. Third, relevance was determined by the physician based on patient history and potential exposure, and nearly always was recorded soon after patch testing. Probable category of relevance represents the most robust elements of the relevance data. On the other hand, possible relevance, which means that the allergen identified can be found in products of the type used by the patient, but confirmation of the actual presence of the allergen in product is not required, is less certain. Furthermore, we were not able to measure the actual concentrations of hexavalent chromium in different samples of cement manufactured in Israel to prove our hypothesis.

In conclusion, the success of European legislation in reducing the concentration of hexavalent chromium in cement, which subsequently reduced the prevalence of cement-induced chromate OACD; together with the poor prognosis and increasing frequency of the disease in northern Israel, should arouse a debate on the implementation of measures to reduce chromate exposure in Israel, specifically by mandating the addition of ferrous sulfate to cement.

REFERENCES

1. Winder C, Carmody M. The dermal toxicity of cement. *Toxicol Ind Health* 2002;18:321–331.
2. Liden C, Bruze M, Menne T. Metals. In: Frosch PJ, Menne T, Lepoittevin JP, eds. *Contact Dermatitis*. 4th ed. Germany: Springer; 2006:537–568.
3. Bock M, Schmidt A, Bruckner T, et al. Occupational skin disease in the construction industry. *Br J Dermatol* 2003;149:1165–1171.
4. Räsänen L, Sainio H, Lehto M, et al. Lymphocyte proliferation test as a diagnostic aid in chromium contact sensitivity. *Contact Dermatitis* 1991;25:25–29.
5. Halbert A, Gebauer K, Wall L. Prognosis of occupational chromate dermatitis. *Contact Dermatitis* 1992;27:214–219.
6. Cahill J, Keegel T, Nixon R. The prognosis of occupational contact dermatitis in 2004. *Contact Dermatitis* 2004;51:219–226.

7. Burrows D, Calnan CD. Cement dermatitis. II. Clinical aspects. *Trans St Johns Hosp Dermatol Soc* 1965;51:27–39.
8. Gammelgaard B, Fullerton A, Avnstorp C, et al. Permeation of chromium salts through human skin in vitro. *Contact Dermatitis* 1992;27:302–310.
9. Avnstorp C. Follow-up of workers from the prefabricated concrete industry after the addition of ferrous sulphate to Danish cement. *Contact Dermatitis* 1989;20:365–371.
10. Finlay AY, Khan GK. Dermatology Life Quality Index (DLQI)—a simple practical measure for routine clinical use. *Clin Exp Dermatol* 1994;19:210–216.
11. Israel Central Bureau of Statistics. <http://www.cbs.gov.il/>
12. Avnstorp C. Cement workers. In: Kanerva L, Elsner P, Wahlberg JE, et al., eds. *Handbook of Occupational Dermatology*. Berlin: Springer; 2000:875–877.
13. Nielsen NH, Menné T. Allergic contact sensitization in an unselected Danish population. The Glostrup Allergy Study, Denmark. *Acta Derm Venereol* 1992;72:456–460.
14. Lantinga H, Nater JP, Coenraads PJ. Prevalence, incidence and course of eczema on the hands and forearms in a sample of the general population. *Contact Dermatitis* 1984;10:135–139.
15. Seidenari S, Manzini BM, Danese P, et al. Patch and prick test study of 593 healthy subjects. *Contact Dermatitis* 1990;23:162–167.
16. Irvine C, Pugh CE, Hansen EJ, et al. Cement dermatitis in underground workers during construction of the Channel Tunnel. *Occup Med (Lond)* 1994;44:17–23.
17. Wang BJ, Wu JD, Sheu SC, et al. Occupational hand dermatitis among cement workers in Taiwan. *J Formos Med Assoc* 2011;110:775–779.
18. Pirilä V, Kajanne A. Sensitization to cobalt and nickel in cement eczema. *Acta Derm Venereol* 1965;45:9–14.
19. Geier J, Krauthelm A, Uter W, et al. Occupational contact allergy in the building trade in Germany: influence of preventive measures and changing exposure. *Int Arch Occup Environ Health* 2011;84:403–411.
20. Fregert S, Gruvberger B. Solubility of cobalt in cement. *Contact Dermatitis* 1978;4:14–18.
21. Hellier FF. The prognosis in industrial dermatitis. *Br Med J* 1958;1:196–198.
22. Fregert S. Occupational dermatitis in a 10-year material. *Contact Dermatitis* 1975;1:96–107.
23. Keczkas K, Bhate SM, Wyatt EH. The outcome of primary irritant hand dermatitis. *Br J Dermatol* 1983;109:665–668.
24. Pryce DW, Irvine D, English JS, et al. Soluble oil dermatitis: a follow-up study. *Contact Dermatitis* 1989;21:28–35.
25. Kalimo K, Kautiainen H, Niskanen T, et al. 'Eczema school' to improve compliance in an occupational dermatology clinic. *Contact Dermatitis* 1999;41:315–319.
26. Adishes A, Meyer JD, Cherry NM. Prognosis and work absence due to occupational contact dermatitis. *Contact Dermatitis* 2002;46:273–279.
27. Holness DL, Nethercott JR. Work outcome in workers with occupational skin disease. *Am J Ind Med* 1995;27:807–815.
28. Lips R, Rast H, Elsner P. Outcome of job change in patients with occupational chromate dermatitis. *Contact Dermatitis* 1996;34:268–271.
29. Hutchings CV, Shum KW, Gawkrödger DJ. Occupational contact dermatitis has an appreciable impact on quality of life. *Contact Dermatitis* 2001;45:17–20.
30. Holness DL. Results of a quality of life questionnaire in a patch test clinic population. *Contact Dermatitis* 2001;44:80–84.
31. Zachariae CO, Agner T, Menné T. Chromium allergy in consecutive patients in a country where ferrous sulfate has been added to cement since 1981. *Contact Dermatitis* 1996;35:83–85.
32. Stocks SJ, McNamee R, Turner S, et al. Has European Union legislation to reduce exposure to chromate in cement been effective in reducing the incidence of allergic contact dermatitis attributed to chromate in the UK? *Occup Environ Med* 2012;69:150–152.
33. Danish Working Environment Service. Statutory Order of the Danish Working Environment Service. No. 661 of 28 November 1983.
34. Johansen JD, Menné T, Christophersen J, et al. Changes in the pattern of sensitization to common contact allergens in Denmark between 1985–86 and 1997–98, with a special view to the effect of preventive strategies. *Br J Dermatol* 2000;142:490–495.
35. Thyssen JP, Jensen P, Carlsen BC, et al. The prevalence of chromium allergy in Denmark is currently increasing as a result of leather exposure. *Br J Dermatol* 2009;161:1288–1293.
36. Roto P, Sainio H, Reunala T, et al. Addition of ferrous sulfate to cement and risk of chromium dermatitis among construction workers. *Contact Dermatitis* 1996;34:43–50.
37. Uter W, Rühl R, Pfahlberg A, et al. Contact allergy in construction workers: results of a multifactorial analysis. *Ann Occup Hyg* 2004;48:21–27.
38. Marks JG, Belsito DV, DeLeo VA, et al. North American Contact Dermatitis Group patch test results for the detection of delayed-type hypersensitivity to topical allergens. *J Am Acad Dermatol* 1998;38:911–918.
39. Olsavszky R, Rycroft R, White I, et al. Contact sensitivity to chromate: comparison at a London contact dermatitis clinic over a 10-year period. *Contact Dermatitis* 1998;38:329–331.
40. Athavale P, Shum K, Chen Y, et al. Occupational dermatitis related to chromium and cobalt: experience of dermatologists (EPIDERM) and occupational physicians (OPRA) in the UK over an 11-year period (1993–2004). *Br J Dermatol* 2007;157:518–522.