

# The Effect of Environmentally Friendly Wallpaper and Flooring Material on Indoor Air Quality and Atopic Dermatitis: A Pilot Study

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**Background:** Formaldehyde (FA) and other volatile organic compounds (VOCs) are considered among the main causes of atopic aggravation. Their main sources include wallpapers, paints, adhesives, and flooring materials. **Objective:** To assess the effects of environmentally friendly wallpaper and flooring material on indoor air quality and atopic dermatitis severity. **Methods:** Thirty patients with atopic dermatitis were enrolled in this study. To improve air quality, the wallpaper and flooring in the homes of the subjects were replaced with plant- or silica-based materials. The indoor air concentration of FA and the total VOCs (TVOCs) were measured before remodeling and 2, 6, and 10 weeks thereafter. Pruritus and the severity of atopic eczema were evaluated by using a questionnaire and the eczema area and severity index (EASI) score before and at 4, 8, and 12 weeks after remodeling. The subjects were instructed to continue their therapy for atopic dermatitis. **Results:** The houses of 24 subjects were remodeled; all subjects completed the study. The concentration of FA in ambient air significantly decreased within 2 weeks after remodeling. The TVOC level showed a decrease at week 2 but increased again at weeks 6 and 10. The reduction of pruritus and EASI score was statistically significant in patients whose baseline EASI score was  $> 3$ . **Conclusion:** Replacing the wallpaper and flooring

of houses with environmentally friendly material reduced FA in ambient air and improved pruritus and the severity of atopic eczema. The improvement of pruritus and eczema was statistically significant in patients whose baseline EASI score was  $> 3$ . (*Ann Dermatol* 26(6) 688~692, 2014)

## -Keywords-

Atopic dermatitis, Formaldehyde, Housing, Indoor air quality, Volatile organic compounds

## INTRODUCTION

The drastic increase of atopic dermatitis in developed countries implies that environmental factors are important in the pathogenesis of the disease<sup>1,2</sup>. The most accepted theory is a hygiene hypothesis: fewer exposures to microbial compounds and fewer infections during early childhood result in a defect of innate immunity and Th2 skewing<sup>1</sup>. Another explanation for the increase of atopic dermatitis is increased exposure to irritants such as traffic-related air pollution and indoor air irritants<sup>1</sup>. However, this has not been thoroughly studied yet and has attracted less attention by researchers. Nevertheless, the results of several epidemiologic studies indicate a strong relation between exposure to irritants and the development of atopic dermatitis<sup>3-7</sup>.

Many patients with atopic dermatitis report the aggravation of eczema after remodeling of their house or moving into a newly built house. Volatile organic compounds (VOCs) including formaldehyde (FA) are considered among the main causes of atopic aggravation<sup>8</sup>, and the main sources of these compounds include paints, adhesives, wallpapers, and flooring materials. Only a few prospective studies have evaluated the effect of air quality on atopic

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eczema. In those studies, air purifier<sup>9</sup> and polyurushiol paint<sup>10</sup> improved both the indoor air quality and atopic dermatitis. This study tested the change of indoor air quality and the severity of atopic eczema after replacing the flooring and wallpaper of the subjects' houses with an environmentally friendly product. To our best knowledge, this is the first study to show the beneficial effect of environmentally friendly flooring and wallpaper material on atopic dermatitis.

## MATERIALS AND METHODS

Thirty patients with atopic dermatitis were enrolled in this study. The enrolled subjects met the major and minor diagnostic criteria of the Korean Atopic Dermatitis Association. Patients with severe atopic dermatitis who require systemic corticosteroid, systemic immunosuppressant, or phototherapy were excluded because they are usually sensitized to aeroallergens and greatly influenced by various aggravating factors. As a result, most subjects were children with mild atopic dermatitis. This study was approved by the institutional review board (IRB) of Seoul National University Bundang Hospital (IRB Approval No. B-1007-105-002), and all subjects gave written informed consent. To improve the ambient air quality, the wallpaper and flooring of the subjects' houses were replaced with plant- or silica-based paper and plant-based flooring material, respectively. The remodeling took place from August to September 2010. Indoor air from the subjects' houses was collected, and the concentration of FA and total VOCs (TVOCs) was measured before remodeling and 2, 6, and 10 weeks thereafter. To measure FA, 30 L of room air was collected in a 2, 4-dinitrophenylhydralazine cartridge and high-performance liquid chromatography was performed. For TVOC measurement, 3 L of room air was collected in a tube filled with 200 mg Tenax-TA (Scientific Instrument Services Inc., Ringoes, NJ, USA) and gas chromatography was performed.

The subjects were followed before and at 4, 8, and 12 weeks after remodeling. Pruritus and the severity of atopic eczema were evaluated, and clinical photographs were taken at each visit. Pruritus was rated on a four-point scale (0 = none, 1 = mild, 2 = moderate, 3 = severe, 4 = very severe) by using a questionnaire. The severity of eczema was evaluated with the eczema area and severity index (EASI) score<sup>11</sup>. The subjects were instructed to continue their ongoing therapy, including topical corticosteroid, topical calcineurin inhibitors, oral antihistamine, and moisturizer, for atopic dermatitis. Those who started systemic corticosteroid, systemic immunosuppressant, or phototherapy during the study period were dropped from the study.

Each measurement at follow-up visit was compared with baseline score using paired t-tests. SPSS ver. 15.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data with *p*-values of <0.05 to be the statistically significant.

## RESULTS

Among the 30 subjects, the houses of 24 of them were remodeled. All of the 24 subjects completed the study; 6 subjects did not participate in house remodeling for personal reasons. The characteristics of the subjects are summarized in Table 1. The baseline EASI score was between 0.5 and 31.6 (mean ± standard deviation [SD], 4.81 ± 7.18). In the 24 subjects, the baseline EASI score was <3 in 14 (58%) subjects and ≥3 in 10 (42%) subjects. The baseline pruritus score was between 2 (moderate) and 4 (very severe) (mean ± SD, 2.6 ± 0.6) (Table 1).

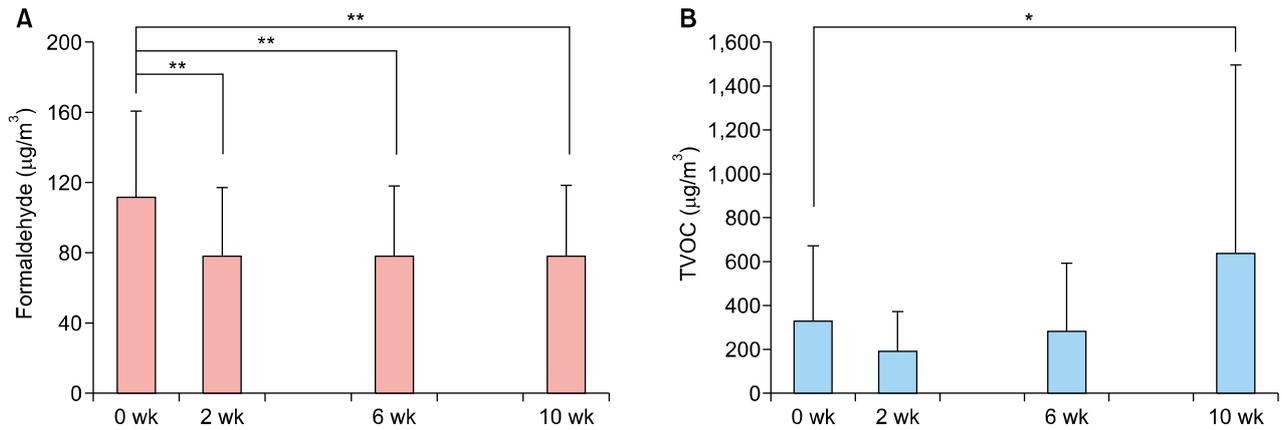
FA in ambient air significantly decreased within 2 weeks after remodeling (*p* = 0.003). The FA level slowly decreased thereafter and reached 63% of its initial level at week 10 (Fig. 1). The TVOCs decreased at week 2. However, at weeks 6 and 10, an elevation of TVOCs was observed (Fig. 1). We performed a Pearson correlation test, which found no significant correlation between indoor air quality and EASI score or pruritus. However, subjects whose indoor FA concentration decreased greater than the mean (−41.9 μg/m<sup>3</sup>) showed a greater reduction of EASI score (−2.69 vs. −1.48).

The mean level of pruritus significantly decreased at week 4 and showed a further decrease at weeks 8 and 12. The mean EASI score also decreased; however, the reduction was not significant (Fig. 2). To check if there is a different response according to the baseline severity of

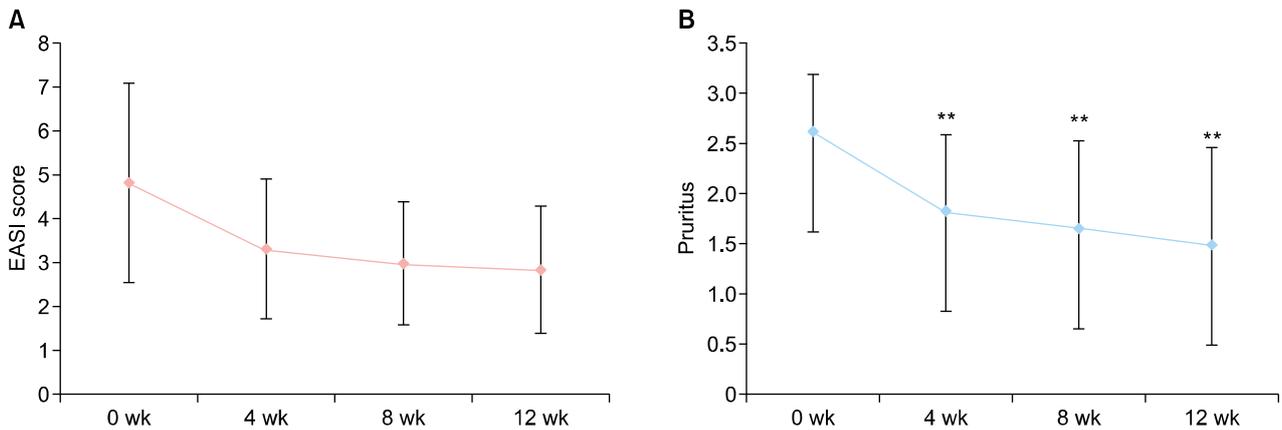
**Table 1.** Characteristics of the subjects (n=24)

Variable	Value
Age (yr)	1 ~ 54 (10.3 ± 12.4)
Sex	
Male	9 (37.5)
Female	15 (62.5)
Duration of atopic dermatitis (mo)	6 ~ 390 (71.3 ± 91.3)
Associated allergic disorder	9 (36)
Asthma	1 (4)
Allergic rhinitis	8 (32)
Baseline EASI score	0.5 ~ 31.6 (4.81 ± 7.18)
Baseline EASI < 3	14 (58)
Baseline EASI ≥ 3	10 (42)
Baseline pruritus score*	2 ~ 4 (2.6 ± 0.6)

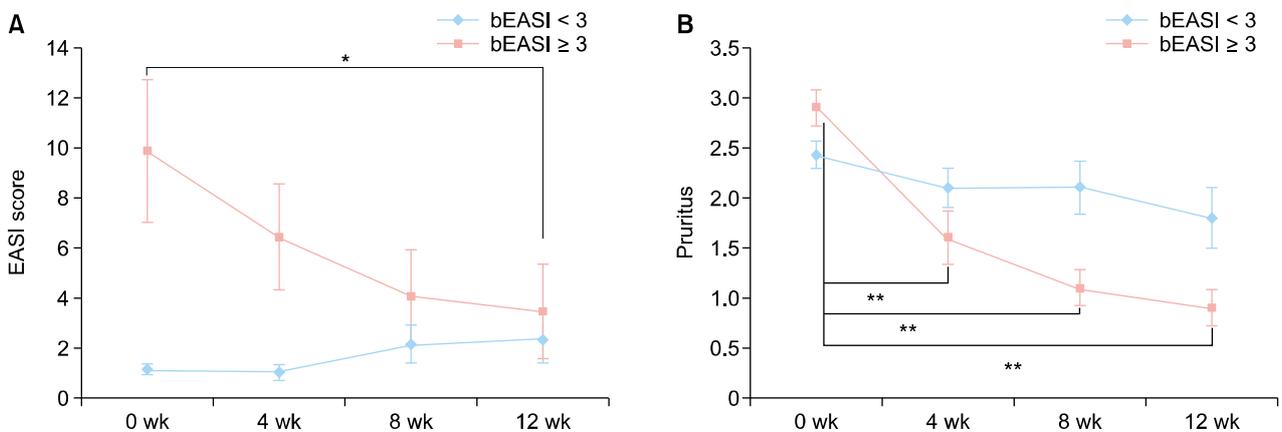
Values are presented as range (mean ± standard deviation) or number (%). EASI: eczema area and severity index. \*0 ~ 4; 0 = none, 1 = mild, 2 = moderate, 3 = severe, 4 = very severe.



**Fig. 1.** Indoor air quality after the replacement of wallpaper and flooring material. (A) After replacement with environmentally friendly wallpaper and flooring materials, the formaldehyde concentration in indoor air statistically significantly decreased at 2 weeks and kept decreasing until week 10. (B) The concentration of total volatile organic compounds (TVOCs) decreased at week 2; however, a re-increase was observed at weeks 6 and 10. \* $p < 0.05$ , \*\* $p < 0.005$ .



**Fig. 2.** Change of pruritus and eczema area and severity index (EASI) score after replacement of wall paper and flooring material. \*\* $p < 0.005$ . (A) EASI score showed a gradual decrease, but the difference was not statistically significant. (B) Pruritus score showed a statistically significant reduction from week 4 and it kept decreasing until week 12.



**Fig. 3.** Change of pruritus and eczema area and severity index (EASI) score after the replacement of wallpaper and flooring materials. (A) In subjects whose baseline EASI (bEASI) score was  $\geq 3$ , a statistically significant reduction of EASI score was observed. The change of EASI score was insignificant in subjects whose bEASI was  $< 3$ . (B) In subjects whose bEASI score was  $\geq 3$ , the level of pruritus was reduced significantly at week 4 and kept decreasing until week 12. The reduction of pruritus was not significant in subjects whose bEASI score was  $< 3$ . \* $p < 0.05$ , \*\* $p < 0.005$ .

atopic dermatitis, subjects whose initial EASI score was <3 (very mild atopic dermatitis) were compared with the others. In patients whose initial EASI score was <3, both pruritus and the EASI score showed a statistically insignificant change. In contrast, the reduction of pruritus and EASI score was statistically significant in patients whose baseline EASI score was >3 (Fig. 3).

## DISCUSSION

VOCs including FA are organic chemicals that have a low boiling point and tend to evaporate at room temperature. They include both man-made and naturally occurring chemical compounds. The major sources of man-made VOCs are latex paints, flooring materials, wall covers, new furnishings, and office equipment such as photocopy machines<sup>12,13</sup>. Indoor VOCs are especially high in newly built houses because of the abundant new materials generating VOC particles simultaneously in a short period<sup>14</sup>. Many patients with atopic dermatitis are concerned about the harmful effect of VOCs, and there are several epidemiologic studies that support those concerns. In a Japanese study, the ambient FA levels during pregnancy and the prevalence of infantile atopic eczema showed a positive, although not statistically significant, correlation<sup>5</sup>. In a study performed for 20,687 pairs of mothers and babies, renovation/painting of the house during pregnancy was significantly associated with infantile eczema, with an odds ratio of 1.99<sup>6</sup>. Because of the growing concerns, many patients with atopic dermatitis seek environmentally friendly housing materials; however, the effect of replacing housing materials with environmentally friendly ones has never been investigated.

FA is a representative VOC. In our study, FA in ambient air significantly decreased within 2 weeks after remodeling and reached 63% of its initial level at week 10. The level of pruritus and the EASI score also decreased accordingly. However, the reduction was significant only in patients whose initial EASI score was >3. This finding is consistent with a previous *in vivo* study; Eberlein-König et al.<sup>15</sup> tested the effect of exposure to low concentrations of NO<sub>2</sub> or FA on epidermal barrier function. In their study, patients with atopic dermatitis showed increased transepidermal water loss after airborne FA exposure, while the barrier function of normal controls was not affected. In our study, changing to environmentally friendly housing materials did not benefit patients with very mild atopic dermatitis. Patients with very mild atopic dermatitis, whose barrier function is relatively intact, seemed to be less affected by indoor air quality.

VOC concentration is known to fluctuate with changing

seasons. VOC concentration in indoor air during winter is known to be three to four times higher than that during summer, owing to the low air exchange rate and the use of humidifiers<sup>16</sup>. In our study, the TVOCs decreased at week 2; however, at weeks 6 and 10, a re-increase of TVOCs was observed. This study was performed from fall to winter, and the re-increase was considered to be caused by increased VOC emission from other sources such as furnishings and adhesives. Despite the increase of TVOCs at weeks 6 and 10, the EASI score and the level of pruritus were improved. VOCs include FA, benzene, toluene, ethylbenzene, xylene, and styrene. In this study, the increase of TVOC was mainly due to an increased concentration of toluene (data not shown). Saito et al.<sup>17</sup> reported that FA induces severe inflammatory reaction in mouse ear at low concentrations (2% ~ 10%), whereas toluene and xylan do not induce inflammatory reaction even at high concentrations (50% or 100%). From our results and that of a previous report, FA seems to play a more important role in eczema aggravation than other VOCs do.

This was only a pilot study and there was no control group. However, this study showed that changing to environmentally friendly housing material could reduce the ambient FA level, and improve pruritus and the severity of eczema in some patients. In addition, we observed that subjects with very mild atopic dermatitis were less affected by indoor air quality than those with more severe eczema, which implies that these airborne irritants are more relevant to patients with a more impaired barrier function.

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