



Scientific Letter

Artificial Stone Silicosis. Progression and Laboral Impact After 3-years Follow-up



To the Director,

The introduction of artificial stone (AS) in industries that handled marble has caused a significant increase in silicosis cases.^{1,2} In 2010, the first cases of silicosis due to AS were published in Spain³ and later they were reported in other countries.^{1,2} To date, information about the evolution of the disease and its laboral consequences is lacking.

This is an observational study in which AS silicosis patients were evaluated between January 2006 and June 2021. Once the diagnosis of the first patient (index case) was completed, the other workers who handled AS from the same company were also evaluated. The diagnosis was based on occupational exposure to AS, radiological findings, and the exclusion of other entities. The chest X-ray was assessed according to the International Labour Office criteria⁴ and high-resolution computed tomography (HRCT) as described by Kusaka et al.⁵ When the diagnosis was not considered certain, a compatible histological sample was required.

The aim of the study was to analyze the clinical, functional, radiological and occupational evolution of a series of AS silicotic patients referred from an occupational health company. A clinical and occupational evaluation, lung function test, chest X-ray and high-resolution computed tomography were performed at diagnosis and at follow-up, at least annually. Silicosis progression was considered if there were radiological changes^{4,5} with or without worsening of dyspnoea⁶ or a functional decrease (FVC \geq 5%/year, FEV₁ \geq 5%/year and DLCO \geq 7.5%/year).^{7–10} The radiological images were analyzed independently by a pulmonologist and a radiologist. If the two evaluators did not agree, the decision was made by consensus. SPSS (v.2.0) and R 4.12 were used for statistical analysis. The patient's informed consent and the approval from the Research Ethics Committee of the Dr. Josep Trueta University Hospital in Girona (CEIM code: 2021/133) were obtained.

Thirty-two patients were included, all men with a mean age of 44.9 \pm 7.6 (Table 1). The mean time of exposure to AS was 21.2 \pm 7.0 years. The most frequent clinical presentation was dyspnoea in 15 of the patients (46.9%). Nine patients (28.1%) had no symptoms. A non-obstructive functional disorder was found in 13 of the patients (40.6%) and an obstructive functional disorder in 9 of them (28.1%). In 10 of the patients (31.2%), the respiratory function was normal. The diagnosis was confirmed by an imaging technique in 84.4% of the patients and by an histological study in the remaining 16.6%. Eighteen of the patients (56.3%) met the criteria for simple silicosis and 14 (43.8%) for complicated silicosis.

Table 1

Demographic Variables and Clinical Characteristics of Silicotic Patients.

Variables	Total Silicotic Patients n = 32
Age (years)	44.9 \pm 7.6
Male	32 (100)
Smoking history	
Non smoker	10 (31.2)
Former smoker	11 (34.4)
Active smoker	11 (34.4)
Average time working marble masons (years)	22.4 \pm 9.9
Average exposure time AS (years)	21.2 \pm 7.0
Protection measures	10 (31.3)
Symptomatology	
Asymptomatic	9 (28.1)
Dyspnoea	15 (46.9)
mMRC 1	9 (28.1)
mMRC 2	5 (15.6)
mMRC 3	1 (3.1)
Cough	13 (40.6)
Chronic bronchitis	3 (9.4)
Hemoptoic expectoration	3 (9.4)
Wheezing	1 (3.1)
Chest pain	1 (3.1)
Rhinitis	1 (3.1)
Weight loss	1 (3.1)
Diagnosis of silicosis	
Chest X-ray	17 (46.7)
Chest CT	10 (36.7)
Lung biopsy	5 (16.6)
Simple silicosis	18 (56.3)
Complicated silicosis	14 (43.8)
Pulmonary function	
FVC % predicted	80.8 \pm 8.8
FEV ₁ % predicted	77.8 \pm 10.4
DLCO % predicted	82.7 \pm 21.1
DLCO/VA % predicted	99.4 \pm 24.4

mMRC: Modified Medical Research Council Dyspnoea Scale; FVC: forced vital capacity; FEV₁: forced expiratory volume in first second; DLCO: diffusing capacity for carbon monoxide; VA: alveolar volume.

Evolution was followed for 39.6 \pm 34.5 months. Three patients (9.3%) progressed from simple to complicated and 1 patient presented an accelerated course. At the end of follow-up, 17 (53.1%) patients were classified as complicated silicosis. Additionally, 10 (31.3%) patients worsened clinically and 14 (43.8%) functionally. There was deterioration of FVC in 12 patients (37.5%), of FEV₁ in 12 of the patients (37.5%), and of DLCO in 4 patients (12.5%) (Fig. 1). The annual reduction of these parameters in those patients was 7.95%, 9.76% and 12.98%, respectively. The probability of verifying

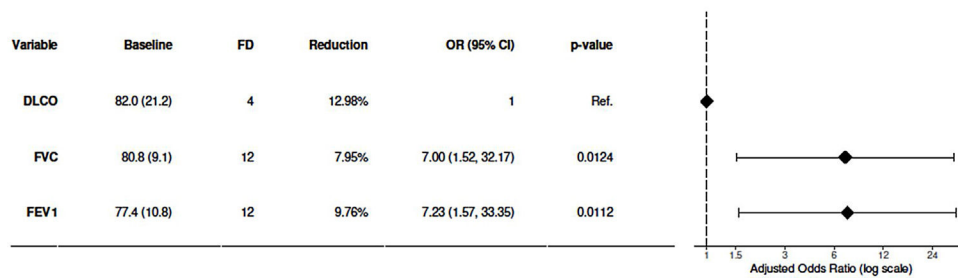


Fig. 1. Evolution of lung function. Forced vital capacity (FVC); forced expiratory volume in first second (FEV₁); diffusing capacity for carbon monoxide (DLCO); number of patients with functional deterioration (FD).

functional decline was 7 times higher when assessed by FVC or FEV₁ than when it was determined by DLCO (Fig. 1). In addition, 2 patients (6.3%) were diagnosed with tuberculosis and 4 (12.5%), all smokers, developed an obstructive functional disorder. Thus, a total of 10 (31.2%) patients were classified as having chronic obstructive pulmonary disease (COPD) at the end of follow-up. Finally, 2 patients (6.3%) underwent transplantation due to silicosis progression.

The 32 patients studied worked in 14 different companies. We obtained reliable information from 9 of the 14 companies included. Twenty-seven out of 61 workers who handled AS were diagnosed with silicosis (44.3% prevalence). After detecting an index case, 24 (88.9%) silicotic patients came together as clusters in the 9 companies studied.

Permanent disability that precluded any employment was provided in 2 (6.3%) of all patients. Permanent disability in terms of the job that caused the silicosis as well as other jobs entailing exposure to the same causative agent was provided in other 27 (84%) of patients. The patient's disability was financially compensated. Additionally, 3 patients (9.4%) diagnosed of simple silicosis without functional impairment had not legal criteria to be subsidized in Spain.¹¹ None of the patients worked as an AS worker after diagnosis. Sixteen (50%) patients became unemployed. We were not aware of the working situation of 3 patients. Only 1 (7.7%) of the remaining 13 patients who found another job, it was in the same company.

Our study has some limitations: the size of the sample was limited, the study was performed in a single centre and data was collected retrospectively.

Patients stand out due to their young age and the lack or limited symptoms at the time of diagnosis. These characteristics would explain that despite the advanced disease stage, they were in full employment. It also remarks the deficiency in adopting prevention measures. Although several studies have reported that 6.6% to 15% of patients with AS silicosis present complicated silicosis at diagnosis,^{12,13} it is very remarkable that 43.8% of our patients were classified with complicated silicosis. These differences could be explained by the fact that the exposure time before diagnosis was 22 years in our study, while in those others studies it was between 7.3² and 15¹⁴ years. During evolution, 3 patients progressed from simple to complicated silicosis, which means that more than half of the patients had this advanced form of the disease at the end of follow-up. Our data, together with a high demand for lung transplantation suggest a serious aggressiveness.

As in other studies^{15,16} a non-obstructive alteration was the most frequent functional pattern found in our patients. However, several studies have also shown that obstruction is a functional alteration often present in chronic silicosis and, as well, in AS silicosis.¹⁴ In our study, 18.8% of the patients presented obstruction at the time of diagnosis and in 12.5% of them it was confirmed at follow-up. Although smoking and other lung diseases such as healed tuberculosis need to be considered, silica is also recognized

as a cause of COPD.¹⁷ A 43.8% of our patients, experienced a significant decrease in lung function. FVC and FEV₁ declined roughly the same rate, as it has also been mentioned in other silicosis.¹⁸ This is indicative of a predominantly restrictive pattern. Moreover, a functional decline was observed more frequently with ventilatory parameters than DLCO. This fact had already been mentioned in other silicosis¹⁹ and has also been recently reported in CAC silicosis.¹²

Based on the detection of index cases, other workers were found and diagnosed with silicosis. Thus, as previously reported,¹ micro-epidemics of silicosis could not be avoided in the companies involved. Although the proper use of screening protocols, surveillance, and awareness of occupational risk in these workers are mandatory,²⁰ it seems clear that other measures are necessary. An adequate evaluation and controlled tests of materials and processes before their introduction in the workplace, should assess the possibility that these changes could pose a risk to the health of workers. Finally, our study found that 50% of the patients became unemployed after the diagnosis of silicosis and only one (7.7%) remained employed in the same company. This fact shows the importance of having suitable legal benefits, given the economic and social consequences that this occupational disease can cause.

Authors' Contributions

RO: (1) the conception and design of the study, acquisition of data, analysis and interpretation of data, (2) drafting the article and revising it critically for important intellectual content, and (3) final approval of the version to be submitted.

AT, MTC, GS: (1) acquisition of data, analysis and interpretation of data, (2) drafting the article and revising it critically for important intellectual content, and (3) final approval of the version to be submitted.

MCC, OTC, MV: (1) analysis and interpretation of data, (2) drafting the article and revising it critically for important intellectual content, and (3) final approval of the version to be submitted.

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Conflicts of Interest

The authors state that they have no conflict of interests.

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References

- Friedman GK, Harrison R, Bojes H, Worthington K, Filios M. Silicosis in a Counter-top Fabricator – Texas, 2014. *MMWR Morb Mortal Wkly Rep.* 2015;64:129–30.
- Hoy RF, Baird T, Hammerschlag G, Hart D, Johnson AR, King P, et al. Artificial stone-associated silicosis: a rapidly emerging occupational lung disease. *Occup Environ Med.* 2018;75:3–5. <http://dx.doi.org/10.1136/oemed-2017-104428>.
- Martinez C, Prieto A, Garcia L, Quero A, Gonzalez S, Casan P. Silicosis, una enfermedad con presente activo. *Arch Bronconeumol.* 2010;46:97–100. <http://dx.doi.org/10.1016/j.arbres.2009.07.008>.
- International Labour Organization (ILO). Guidelines for the use of the ILO international classification of radiographs of pneumoconioses (revised edition 2011). Geneva: International Labour Organization; 2011.
- Kusaka Y, Hering KG, Parker JE. International classification of HRCT for occupational and environmental respiratory diseases. Tokyo: Springer Verlag; 2005.
- Fletcher CM. Standardised questionnaire on respiratory symptoms: a statement prepared and approved by the MRC Committee on the Aetiology of Chronic Bronchitis (MRC breathlessness score). *BMJ.* 1960;2:1665.
- Storebo ML, Eagan TML, Eide GE, Gulsvik A, Thorsen E, Bakke PS. Change in pulmonary diffusion capacity in a general population sample over 9 years. *Eur Clin Respir J.* 2016;3. <http://dx.doi.org/10.3402/ecrj.v3.31265>.
- George PM, Spagnolo P, Kreuter M, Altinisik G, Bonifazi M, Martinez FJ, et al. Progressive fibrosing interstitial lung disease: clinical uncertainties, consensus recommendations, and research priorities. *Lancet Respir Med.* 2020;8:925–34. [http://dx.doi.org/10.1016/S2213-2600\(20\)30355-6](http://dx.doi.org/10.1016/S2213-2600(20)30355-6) [PMID: 32890499].
- Sherrill DL, Enright PL, Kaltenborn WT. Predictors of longitudinal change in diffusing capacity over 8 years. *Am J Respir Crit Care Med.* 1999;160:1883–7.
- Thomas ET, Guppy M, Straus SE, Bell KJL, Glasziou P. Rate of normal lung function decline ageing adults: a systematic review of prospective cohort studies. *BMJ Open.* 2019;9:e028150. <http://dx.doi.org/10.1136/bmjopen-2018-028150>.
- Ruiz J, Alfageme I, Chiner E, Martinez C. Valoración de la discapacidad en los enfermos respiratorios. *Arch Bronconeumol.* 2012;48:290–5. <http://dx.doi.org/10.1016/j.arbres.2011.12.005>.
- Jimenez AL, Hidalgo A, Conde MA, Perez A, Morales JM, Garcia EM, et al. Artificial stone silicosis rapid progression following exposure cessation. *Chest.* 2020;158:1060–8. <http://dx.doi.org/10.1016/j.chest.2020.03.026>.
- Edwards G. Accelerated silicosis – An emerging epidemic associated with engineered stone. Comment on Leso, V. et al. Artificial stone associated silicosis: a systematic review. *Int J Environ Res Public Health.* 2019;16:1179. <http://dx.doi.org/10.3390/ijerph16040568>.
- Martinez C, Prieto A, Garcia L, Fernandez L, Moreda A, Fernández R, et al. Silicosis en trabajadores con conglomerados artificiales de cuarzo. *Arch Bronconeumol.* 2019;55:459–64. <http://dx.doi.org/10.4321/s0465-546x2022000100002>.
- Kramer MR, Blanc PD, Fireman E, Amital A, Guber A, Rahaan NA, et al. Artificial stone silicosis (corrected): disease resurgence among artificial stone workers. *Chest.* 2012;142:419–24. <http://dx.doi.org/10.1378/chest.11-1321>.
- Pérez A, Córdoba JA, Millares JL, Figueroa E, García C, Romero J. Outbreak of silicosis in Spanish quartz conglomerate workers. *Int J Occup Environ Health.* 2014;20:26–32.
- National Institute for Occupational Safety and Health (NIOSH). Crystalline silica: health risks; 2019. <https://www.cdc.gov/niosh/topics/silica/risks.html>
- Ng TP, Chan SL, Lam KP. Radiological progression and lung function in silicosis: a ten year follow up study. *Br Med J.* 1987;295:164–8. <http://dx.doi.org/10.1136/bmj.295.6591.164>.
- Teculescu DB, Stanescu DC. Carbon monoxide transfer factor for the lung in silicosis. *Scand J Respir Dis.* 1970;51:150–9.
- Hoy RF, Glass DC, Dimitriadis C, Hansen J, Hore-Lacy F, Sim MR. Identification of early-stage silicosis through health screening of stone benchtop industry workers in Victoria, Australia. *Occup Environ Med.* 2021;78:296–302. <http://dx.doi.org/10.1136/oemed-2020-106897>.

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