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Evaluation of dental technician's pneumoconiosis using chest X-ray and HRCT: correlation between radiological and functional findings

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Background/aim: This study aimed to compare high-resolution computed tomography (HRCT) findings with those of chest X-ray (CXR) and to evaluate the relationship of pulmonary function test (PFT) parameters with HRCT and CXR findings in cases of dental technician's pneumoconiosis.

Materials and methods: CXR, PFT, and HRCT data of 89 dental technicians who were diagnosed with pneumoconiosis were retrospectively evaluated.

Results: The cases of 24 dental technicians (27%) classified as normal (Category 0) based on CXR were evaluated as Category 1 according to HRCT. There was an inverse correlation of PFT parameters with nodular profusion score in CXR and all HRCT parameters. In this participant sample, small opacities were predominant (70% of the individuals), and worsening of PFT parameters was associated with the prevalence of pulmonary parenchymal changes.

Conclusion: In the present study, micronodules detected using HRCT had an effect on pulmonary function worsening, which has not been reported in previous studies.

Key words: Pneumoconiosis, dental technicians, high-resolution computed tomography, pulmonary function tests

1. Introduction

Dental technicians are exposed to silica, hard metals, aluminum oxide, acrylic, resins, and ceramics due to their occupational conditions. Exposure to these factors may lead to interstitial lung diseases known as dental technician's pneumoconiosis (DTP) (1–3).

The diagnosis of pneumoconiosis is based on the radiological findings of the parenchymal changes caused by occupational exposure. However, many parenchymal structures overlap in a chest X-ray (CXR), limiting its specificity and sensitivity. Therefore, pneumoconiosis in those with dust exposure cannot be ruled out using conventional radiographs (4), whereas high-resolution computed tomography (HRCT) plays an important role in disclosing early changes observed in occupational respiratory diseases, such as DTP. In various studies, it has been shown that HRCT is more sensitive than a CXR for the detection of opacities (5,6) and emphysema as well the determination of its extent (7–12).

In the follow-up and evaluation of pneumoconiosis cases, radiological methods and pulmonary function tests (PFTs) are commonly used. Many studies have been carried out to demonstrate the relationship between these two methods and the effects of the degree of pneumoconiosis, cigarette consumption, extent of emphysema, and duration of exposure on pulmonary functions, and the correlations between HRCT and PFTs have been investigated (2,7,9–14).

Not many studies have reported the relationship between the impairment of pulmonary functions in dental technicians and radiological findings. In this professional category, there is only a small case series demonstrating the correlation between pulmonary functions and HRCT (15). In the present large case-series study (n = 89), we aimed to evaluate the correlation between HRCT and PFT parameters in dental technicians and to compare the HRCT findings with those of CXR.

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2. Materials and methods

2.1. Study population

Patients with HRCT parenchymal findings confirmed as DTP from a hospital database system from June 2006 to June 2011 were included in the study. The same database, with a different study period, was also used to determine the possible risk factors for DTP in our previous publication (14). Biopsy findings were available for only four patients. Their clinical and radiological findings were retrospectively evaluated.

Apart from their occupation as a dental technician, none of the patients had any previous occupational dust exposure. The diagnosis of pneumoconiosis was based on a history of exposure to mixed dust and HRCT findings consistent with pneumoconiosis. The study was approved by the Human Ethics Committee of Dışkapı Yıldırım Beyazıt Training and Research Hospital.

2.2. Radiologic examinations

2.2.1. CXR

CXRs were taken using the US X-Ray (500 mA) conventional device in a posteroanterior position with a short exposure time (0.1 s). To obtain images, computerized radiography was used with the Kodak Direct View Elite CR system, and the hard copies of the images were printed using a Kodak DryView 8900 Laser Imager.

CXRs were evaluated based on the International Labor Organization (ILO) classification by three blinded readers, including an experienced thoracic radiologist and two chest physicians; the radiologist and one of the chest physicians were certified ILO readers.

If there was an inconsistency between the three readers, they jointly reevaluated the CXRs until reaching a consensus. Patients with an ILO category of 1/0 and over were considered to have pneumoconiosis. For profusion scores, the complete set of ILO 2000 standard radiographs was used. The profusions were assessed and recorded according to the following categories: 0 (0/–, 0/0, 0/1); 1 (1/0, 1/1, 1/2); 2 (2/1, 2/2, 2/3); and 3 (3/2, 3/3. 3/+). The shapes and sizes of the opacities were also evaluated according to the ILO 2000 standard radiographs. The predominant shapes and sizes were expressed as p, q, r, s, t, or u. Large opacities were classified as sizes A, B, or C (16).

2.2.2. HRCT

The HRCT images were acquired using a GE HiSpeed scanner (General Electric Medical Systems). Slices of 1 mm in thickness were obtained at 10-mm intervals from the apex to the base of the lung. An image reconstruction technique was performed using a 512 × 512 pixel matrix with a high-resolution algorithm.

HRCT images were interpreted in a randomized manner by a radiologist in a different session (without CXRs).

In HRCT examinations, parenchymal nodular opacities with a diameter of less than 10 mm were classified as small and those larger than 10 mm were classified as large opacities (5,10,12,17).

Small opacities were evaluated into four categories according to their profusion:

0 = no nodules;

1 = a small number of nodules without vascular blurring;

2 = a large number of nodules with or without vascular blurring, but with no confluence;

3= a large number of nodules having confluence in some areas and accompanied by vascular blurring, with the diameter of the nodules' confluence less than 10 mm.

Large opacities were measured at their greatest width. The opacities in both the lungs having a width greater than 10 mm were all summed and categorized as follows (12):

A = a total width of more than 10 mm and less than 50 mm of one or more opacities in both lungs;

B = a total width of more than 50 mm and less than 100 mm of one or more opacities in both lungs;

C = a total width of one or more opacities exceeding 100 mm in both lungs.

Besides the profusion of the nodules, HRCT images of the patients were evaluated according to the total interstitial involvement of the parenchyma.

Total interstitial disease (e.g., nodules, masses, emphysema, and other parenchymal alterations) scores (18):

0 = no alteration (normal findings);

1 = pulmonary involvement of ≤5% of the area;

2 = pulmonary involvement from >5% to ≤25% of the area;

3 = pulmonary involvement from >25% to ≤50% of the area;

4 = pulmonary involvement from >50% to ≤75% of the area;

5 = pulmonary involvement >75% of the area.

Scores for the total extent of parenchymal opacities, including nodules and masses (18):

0 = no parenchymal opacities;

1 = parenchymal opacities involving ≤5% of the area;

2 = parenchymal opacities involving >5% to ≤25% of the area;

3 = parenchymal opacities involving >25% to 49% of the area;

4 = parenchymal opacities involving 50% to 75% of the area;

5 = parenchymal opacities involving >75% of the area.

Score for the extent of the emphysema (18):

0 = no emphysema;

1 = emphysema affecting ≤5% of the area;

2 = emphysema affecting >5% to ≤25% of the area;

3 = emphysema affecting >25% to 49% of the area;

4 = emphysema affecting 50% to 75% of the area;

5 = emphysema affecting >75% of the area.

These scores were applied to five different levels of the lung parenchyma (19). Because the parenchymal area differed at each level, influence factors were used (20). Following are the levels and the influence factors (in parenthesis):

1. Origin of the major vessels (1.29);
2. Aortic arch (1.90);
3. Carina (2.22);
4. Confluence of the pulmonary veins (2.28);
5. One centimeter above the right diaphragm (2.30).

At each level, both the right and left lung were evaluated according to the percentage of the parenchymal involvement. The sum of the right and the left lung scores was then multiplied by the influence factor at each level, and the values at each level were summed to obtain the total score (18).

2.3. Clinical parameters

Demographic information, smoking status, and the overall duration of employment (total duration of dust exposure) were recorded in evaluation form results.

PFTs were interpreted as per the American Thoracic Society standards (21). Standard spirometry measurements were performed using dry-seal-spirometry (ZAN 100, nSpire Health Inc., Oberthulba, Germany). The diffusing capacity of the lungs for carbon monoxide (DLCO) and lung volume parameters were measured using the single-breath DLCO procedure (ZAN 100).

2.4. Statistical analysis

SPSS 21.0 was used to evaluate the variables. Numeric variables are presented as mean ± standard derivation and categorical variables were expressed as percentages. The chi-square test was used for the analysis of categorical variables; the Kruskal–Wallis test was used for comparison of continuous variables that were not normally distributed among the various groups. The Mann–Whitney U test with a Bonferroni correction was used for posttest analysis after performing the Kruskal–Wallis test. The κ coefficient was used to evaluate the agreement between two observers, and the Spearman correlation test was used to assess the possibility of a relationship between two quantitative variables. Multiple regression analysis was used for predicting pulmonary functions from HRCT parameters. P-values less than 0.05 were considered as significant.

3. Results

3.1. Clinical data

In total, 89 dental technicians (88 males, 1 female) with a mean age of 35.08 ± 6.81 years were included in the present study. The mean duration of dust exposure was 16.24 ± 6.78 years. Of the 89, 65 patients were smokers, while 24 were nonsmokers. The mean pack-year value was 12.62 ± 7.78 pack-years.

Table 1 presents the distribution of the clinical findings, pulmonary functions, and radiological parameters of 89 patients with DTP. For small opacity profusion categories, the only affected pulmonary function parameter was airflow (i.e. FEV_1, FEV_1/ FVC, and FEF_{25-75}). However, in the presence of large opacities, all the parameters, including airflow, lung volume, and DLCO, were affected. There was no significant difference between the emphysema scores with the small opacity scores, whereas they were significantly different in the presence of large opacities.

The pulmonary functional disturbance distribution was as follows: 23 patients had an obstructive, 7 had a restrictive, and 4 had a mixed-type respiratory disorder. DLCO was found to be decreased in 14 individuals. Of these, 13 had a mild and 1 had a moderate reduction.

3.2. CXR and HRCT data

3.2.1. CXR

Among CXRs, 62 were evaluated as quality 1 and 27 as quality 2. According to the profusion of small opacities, the results were as follows: category 0: 24 (27%), category 1: 19 (21.3%), category 2: 24 (27%), and category 3: 22 (24.7%).

The classification of small opacities according to sizes and shapes was as follows: q/q = 19, p/q = 11, q/r = 11, p/p = 19, p/s = 13, p/r = 1, q/p = 3, r/r = 6, q/t = 6, u/u = 2, and s/s = 1.

Large opacities were observed in CXRs of 13 patients (14.7%): Category A, 3 (3.3%); Category B, 3 (3.3%); and Category C, 7 (7.8%) patients.

According to the small opacity profusion (categories 0, 1, 2, and 3), the κ coefficient of the reliability between readers was found to be 0.454 ($P < 0.001$). For large opacities (0, A, B, and C), the determination of the κ coefficient of reliability between readers was 1 ($P < 0.001$).

3.2.2. HRCT data

A small opacity was observed in the HRCT of all the patients (100%); progressive massive fibrosis (PMF) was found in 19 patients (21.3%). For small opacities, the consistency between the two methods (i.e. CXR and HRCT) was found to be 20.5% ($P < 0.001$). In total, 24 patients (27%) were classified as Category 0 according to CXR and were reclassified as Category 1 according to the HRCT findings. For large opacities, the consistency between the two methods was found to be 79.4% ($P < 0.001$). The number of cases with a large opacity that was not detected using a CXR before HRCT was 6 (7.8%) (Figures 1a and 1b).

Table 1. Demographics, spirometry, and HRCT results according to the small and large opacity categories.

		Small opacities			P	Large opacities			P
		1	2	3		A	B	C	
Clinical‡	Total sample n = 89	n: 39	n: 17	n: 14		n: 7	n: 5	n: 7	
Age (years)	35.8 ± 6.81	35.03 ± 6.78	33.47 ± 6.49	38.00 ± 6.69	0.248	35.14 ± 6.89	31.80 ± 9.44	35.71 ± 6.07	0.647
Amount of smoking, packs/year	9.21 ± 8.70	10.74 ± 8.68	8.53 ± 8.69	10.43 ± 9.25	0.704	7.14 ± 9.51	5.80 ± 7.95	4.43 ± 7.23	0.170
Dust exposure duration (years)	16.24 ± 6.78	15.03 ± 5.31	13.47 ± 6.96	22.93 ± 6.07	0.000*	19.29 ± 6.07	14.20 ± 8.37	14.71 ± 7.06	0.572
Pulmonary function †									
FEV_1	83.19 ± 18.06	91.23 ± 11.27	89.33 ± 13.89	69.94 ± 19.50†	0.034*	78.86 ± 21.30	67.00 ± 3.53	50.43 ± 13.24	0.000*
FVC	89.51 ± 14.73	95.31 ± 11.14	92.78 ± 10.56	80.59 ± 16.49	0.090	86.86 ± 17.64	75.60 ± 6.50	65.00 ± 15.10	0.000*
FEV_1/FVC	78.36 ± 9.71	82.36 ± 6.76	81.22 ± 9.31	72.53 ± 10.44	0.003*	80.71 ± 15.39	72.20 ± 2.58	65.57 ± 10.70	0.005*
FEF_{25-75}	65.98 ± 26.34	76.92 ± 20.85	74.06 ± 23.61	53.36 ± 22.32	0.005*	66.14 ± 32.27	41.80 ± 6.79	27.71 ± 10.95	0.000*
PEF	78.09 ± 22.89	85.82 ± 19.46	82.89 ± 25.04	67.94 ± 22.57	0.518	69.86 ± 27.77	67.60 ± 15.09	54.43 ± 11.58	0.005*
TLC	102.14 ± 22.08	96.34 ± 14.39	98.86 ± 14.46	96.10 ± 10.04	0.897	87.50 ± 20.34	78.50 ± 9.81	75.50 ± 9.81	0.001*
RV	39.91 ± 38.02	129.65 ± 33.59	143.86 ± 78.17	125.50 ± 15.38	0.995	105.66 ± 17.79	95.25 ± 23.65	93.80 ± 28.83	0.005*
DLCO	102.14 ± 22.08	106.31 ± 19.44	109.00 ± 18.41	111.20 ± 21.15	0.645	80.33 ± 18.52	74.00 ± 13.03	63.00 ± 13.69	0.000*
Radiological◆									
Total score	39.96 (6.38–99.90)	26.36 (6.38–85.89)	46.18 (33.06–77.34)	62.62 (34.80–95.40)	0.000*	63.7 (41.5–85.3)	78.9 (40.8–99.9)	80.5 (54.3–99.9)	0.000*
pacO score	42.39 (6.38–86.30)	26.20 (6.38–85.89)	43.76 (22.08–77.34)	59.58 (26.20–86.30)	0.000*	58.6 (41.5–71.0)	63.4 (39.5–83.0)	68.1 (43.4–75.3)	0.000*
Emphysema score	0.0 (0.0–69.34)	0.0 (0.0–26.1)	0.0 (0.0–14.3)	2.5 (0.0–20.62)	0.113	0.0 (0.0–40.6	22.9 (1.2–49.5)	25.8 (0.0–69.3)	0.000*

FEV_1: Forced expiratory volume in 1 s; FVC: forced vital capacity; FEF_{25-75}%: forced expiratory flow between 25% and 75% of FVC; HRCT: high-resolution computed tomography; PEF: peak expiratory flow; TLC: total lung capacity; RV: residual volume; DLCO: diffusing capacity of the lung for carbon monoxide; pacO: parenchymal opacities. * Significant difference. † Data are the mean percentage of the predicted values ± standard deviation. ‡ Data are the mean values ± standard deviation. ◆ Data are the median values. Numbers in parentheses are ranges. Small opacities were found in only 70 patients, and 19 patients had both small and large opacities.

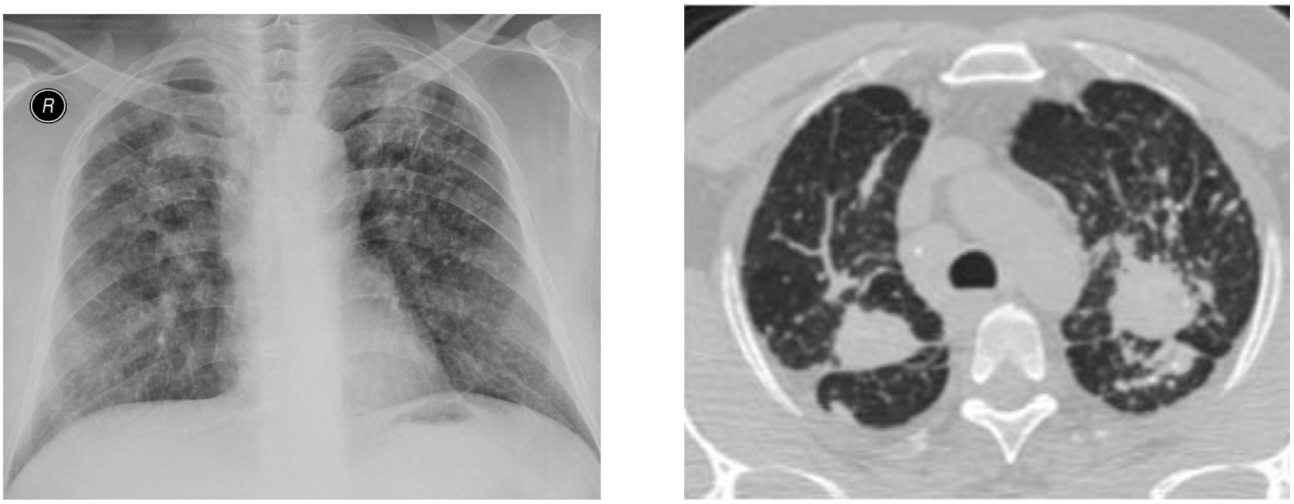

Figure 1. a) On the chest X-ray, large opacities at both upper lobes of the lung were hardly detected due to the rib superposition. b) With high-resolution computed tomography, 35-mm-wide large opacities are easily demonstrated, bilaterally in the upper zones.

3.2.3. Correlations among CXR, HRCT, pulmonary function, and clinical parameters

In Table 2, the relationship between CXR, CT, and pulmonary functions is summarized. There was inverse correlation between all radiological findings and pulmonary function parameters: CXR [nodular profusion (NP): FVC (r = –0.448, P < 0.001; FEV_1 (r = –0.460, P < 0.001)] and all HRCT parameters [NP: FVC (r = –0.447, P < 0.001), FEV_1 (r = –0.496, P < 0.001); total score: FVC (r = –0.499, P < 0.001), FEV_1 (r = –0.446, P < 0.001); and parenchymal opacities score: FVC (r = –0.417, P < 0.001), FEV_1(r = –0.400, P < 0.001)].

While the emphysema score was negatively correlated with airway flow [FEV_1/FVC (r = –0.351, P = 0.001), $FEF_{25–75}$ (r = –0.419, P < 0.001), and DLCO (r = –0.418, P < 0.05)], that was not the case with cigarette consumption (r = –0.034, P > 0.05). The opacity score had a moderate correlation with air flow and lung volume and a weak correlation with DLCO. No association was found between cigarette consumption and the duration of dust exposure as well as the CXR, HRCT, and pulmonary function parameters.

4. Discussion

In epidemiological studies, in order to define radiographic abnormalities for any type of pneumoconiosis, CXRs are evaluated according to the ILO classification (16). The effectiveness of this classification in clinical diagnosis is controversial as it has high variability between readers, particularly in low profusion categories, and underestimates the actual severity of the disease (5). In the present study, while there was complete consistency between the readers for large opacities, there was a large discrepancy for small opacities. The results of this study are compatible with those of studies reporting high κ values for large opacities (5,10,22). Despite these limitations, CXR is still the most efficient tool for the evaluation of parenchymal changes seen due to dust exposure because of low cost and low radiation exposure (22).

Many studies have been carried out to determine the significance of early detection of small opacities. In a Chinese study including 90 mining machinery manufacturer workers, CXR and HRCT findings were consistent for 72 workers, while there was discordance for 18 cases. Using HRCT, silicosis was detected in 8 of 30 patients, with CXR findings being negative (4). In a Polish study involving 64 foundry workers, the radiographic findings were normal; however, nodules were detected in 47% of the patients via HRCT scans (23).

In one study, 166 dental technicians from Denizli, Turkey, were assessed using CXR and HRCT, and reticulonodular opacity was detected in 47 (28.8%) using the former, while pneumoconiosis was detected only in 10 (6%) using the latter. The low rate of pneumoconiosis detected using HRCT could only have been caused by the application of HRCT to people with lesions in the CXR (24).

Table 2. Relationship among pulmonary function, CXR, and HRCT parameters.

Radiologic parameter*		FVC	FEV_1	FEV_1/FVC	$FEF_{25–75}$	PEF	TLC	RV	DLCO
NP at CXR	r P	–0.448 0.000	–0.460 0.000	–0.320 0.002	–0.416 0.000	–0.366 0.000	–0.284 0.014	–0.223 0.055	–0.207 0.075†
NP at CT	r P	–0.447 0.000	–0.496 0.000	–0.425 0.000	–0.500 0.000	–0.295 0.005	–0.289 0.012	–0.252 0.029	–0.258 0.027
Total score	r P	–0.449 0.000	–0.446 0.000	–0.266 0.012	–0.376 0.000	–0.386 0.000	–0.339 0.003	–0.297 0.010	–0.016 0.019
pacO score	r P	–0.417 0.000	–0.400 0.000	–0.209 0.049	–0.309 0.003	–0.369 0.000	–0.337 0.001	–0.337 0.003	–0.238 0.040
Emphysema score	r P	–0.221 0.037	–0.298 0.005	–0.351 0.001	–0.419 0.000	–0.218 0.40†	–0.092 0.433†	–0.042 0.718†	–0.318 0.005

Relationship between the radiologic parameter and pulmonary function parameter was significant (P < 0.05). r = Spearman rank correlation coefficient. CXR: chest X-ray; FEV_1: forced expiratory volume in 1 s; FVC: forced vital capacity; $FEF_{25–75}$%: forced expiratory flow between 25 and 75% of FVC; HRCT: high-resolution computed tomography; PEF: peak expiratory flow; TLC: total lung capacity; RV: residual volume; and DLCO: diffusing capacity of the lung for carbon monoxide, pacO: parenchymal opacities. All pulmonary function test parameters were expressed as the percentage of predicted value. * With exception of the nodular profusion (NP) for the chest X-ray, all parameters were measured using CT. † The relationship between the radiologic and pulmonary function parameters was not significant.

In the present study, 24 patients (27%) classified as Category 0 according to the CXR findings were reclassified as Category 1 according to the HRCT findings. Thus, it was demonstrated that HRCT is more sensitive in detecting small opacities in the early period.

HRCT was also superior to the CXR in detecting large opacities. In a study with 41 stone-carving workers from Brazil, large opacities using HRCT were detected in four subjects in whom PMF was not detected using CXR (22). In the present study, using HRCT, large opacities were detected in 19 patients, whereas they were detected in only 13 patients using CXR.

Regarding PFTs, 38.2% of our study patients were found to have a ventilatory defect (obstructive or mixed). Pneumoconiosis leads to airflow limitation via different mechanisms. These consist of bronchial stenosis secondary to peribronchial fibrosis, enlargement of lymph nodes, and centrilobular emphysema (12,25). The idea that coalescence and PMF contribute to pulmonary function defects is not novel. The PMF masses, consisting of fibrotic nodule clusters, may lead to lung parenchymal distortion, and an increase in the irregular areas in the adjacent aeration zones may ultimately result in airflow limitation (7,9–11).

In the HRCT results of the present study, 21.3% of the patients were evaluated as having PMF with large opacities and accompanying scar-associated emphysema. This may be the underlying mechanism of airway obstruction.

The comparison of pulmonary function parameters with different HRCT categories showed significant differences in the functional parameters (airflow, FEV_1, FEV_1/FVC, and $FEF_{25–75,\ 50,\ 25}$) in our study. Pathologically, silicotic nodules are observed in the peribronchiolar and perivascular interstitium as well as the paraseptal and subpleural interstitium. These nodules frequently obliterate bronchioles and pulmonary arteries, leading to airway obstruction (26). Nevertheless, the correlation between radiological pneumoconiosis and functional obstruction measurements is debatable (10,17). This effect is due to the direct bronchial obliteration due to silicotic nodules. In previous studies, micronodules in HRCT with no large opacities were not reported to be associated with pulmonary functional worsening (17,18,27). However, in the present study, there was no significant difference between small opacity categories with respect to smoking habits and emphysema scores. Therefore, we ascribed pulmonary function disturbances to the micronodules. Additionally, in the present study, a large opacity in the HRCT images was associated with a decrease in DLCO and airflow parameters. These parameters decreased as the extent of the large opacities increased. These findings were compatible with those of other studies, which demonstrated that large opacities exhibit a strong correlation with lung function impairment compared with that exhibited by the small ones (10–12,28). Therefore, the presence of large opacities detected in HRCT is an important indicator of pneumoconiosis severity (10,12).

In the present study, as in others, there was a negative correlation between the parenchymal large opacities and the decrease in DLCO (11,12,28). Moreover, while there was no difference regarding DLCO between different HRCT small opacity categories, DLCO was decreased markedly in the presence of large opacities.

Some investigators attribute this correlation to the presence of PMF, which leads to scar-associated emphysema and a decrease in the surface available for gas exchange, resulting in a decreased DLCO. As in our study, the decrease in DLCO gradually diminished as the category of the large opacity increased.

A study conducted in Turkey (patients, n = 32) found that there was a negative correlation of the CXR and HRCT opacity scores with functional parameters (FEV1, %FVC, and %FEV1). In this study, only eight patients were diagnosed with pneumoconiosis, and the HRCT scoring was performed primarily on the basis of the presence of small opacities (15).

In this study, we evaluated the radiological and functional parameters of patients who were diagnosed as having DTP. Another important aspect of this study is that the HRCT analysis included not only small opacities but also other parenchymal findings, such as emphysema, bronchiectasis, and large opacities. Therefore, the relationship between radiologically detected pathologies caused by dust exposure and the decrease in functional parameters was meticulously analyzed.

In another study, evaluating 76 dental technicians, a negative correlation of respiratory function tests was found with round opacities identified using HRCT and the work performed during the year (29).

In a cross-sectional study evaluating 64 denim sandblasters using multiple detector computed tomography (MDCT), a significant correlation was found between the nodular perfusion score and silica exposure time. However, no correlation between age and smoking was found. In our study, neither the duration of exposure nor smoking had any relationship with pulmonary functions and radiographic parameters (30).

A potential limitation of the present study was that the dose and incidence of the professional exposure could not be quantified. Another limitation was the evaluation of HRCT by a single radiologist, which made it impossible to evaluate the consistency coefficients of the HRCT readings.

In conclusion, the present study demonstrated that in the diagnosis of DTP, HRCT screening is superior to CXR for the early detection of the disease onset as well as the detection of PMF; HRCT evaluation of DTP revealed a morphological and functional correlation. We demonstrated that the degree of radiological findings was closely related to airway obstruction. Our study has shown

that high profusion of small opacities by themselves may cause pulmonary functional impairment even if there is no PMF.

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