Dose Response Relationship between Exposure to Hand–Arm Vibration and Health Effects among Dentist at Workplace

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Abstract Dentists have neurological symptoms in the dominant hand. In this paper, examining different stages of processing in a dental laboratory, we analyze noise and mechanical vibrations. The investigation allow us to assess the exposure to noise and vibration of the worker and to identify the stages of processing more harmful to the health of the worker. The vibration exposure can be analyzed on the hand–arm system of the worker by means of the cross–correlation of the noise and of the accelerations in the time domain and in the frequency domain. [DOI:10.12866/J.PIVAA.2013.09.003]\textsuperscript{1}

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1 Introduction

Dentists can have neurological symptoms in their hands. Dentists can have a slightly higher vibration threshold in the dominant hand, which is exposed to high–frequency vibrations, in comparison with the non dominant hand [Szymanska, 2001]. Examining nerve injury to the fingers of dental workers, sensitivity to vibration, temperature and pain, there are differences in the reception of vibration, temperature and heat pain between dominant and non dominant hands [Ekenvall et al., 1990]. Researchers examine effects with long–term exposure to vibration and with short–term exposure [Gijbels et al., 2006]. Dentists with long–term exposure have higher vibration thresholds than dentists with short–term exposure [Mansfield, 2005]. In fact, dentists with long–term exposure reveal neurological symptoms in the dominant hand more often than the dentist with short–term exposure, because long–term exposure increases the risk of finger symptoms [Myers and Myers, 2004]. The risk of hand/wrist disorders and severity of the symptoms depends on intensity and duration of exposure to vibrating tools. The period between initial exposure to vibration and the onset of symptoms is the latency period, that can vary between individuals, because of the differences in the exposure pattern (combination of vibration with repetition, force, awkward posture)

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and individual susceptibility. The symptoms appear after 2000 h of vibration exposure. There is a positive association of body mass index (BMI) with neck, shoulder, low back and knee pain. High BMI was associated with osteoarthritis in several joints, especially in the knees but also in the hands and with the severity of carpal tunnel syndrome [Torbica and Krstev, 2006]. Rytknen et al. measured the vibrations of turbines and slow-speed handpieces. Such vibrating handpieces may be responsible for neurological signs and symptoms amongst dental personnel. A cumulative effect over many years may be related to symptoms of hand–arm vibration syndrome such as tingling, numbness or pain [Rytknen et al., 2006].

Also, the carpal tunnel is caused by constant grips or repetitive injury. The work of the dentist is characterized by repetitive hand grips demanding high precision, with the elbows bent, the shoulders often abducted, and the cervical spine flexed and rotated. The carpal tunnel syndrome is common in occupational groups with repetitive hand movements. Ulnar entrapment at the elbow is common in people working with repetitive elbow movements. Dentists have a high frequency of neck and shoulder symptoms and a high prevalence of cervical spondylosis.

Vibration White Finger (VWF) arouses symptoms which can make dental practice more difficult. The symptoms continue from 20–45 minutes from the beginning of the symptoms. In cold weather they can persevere even for several hours. Frequency levels at which VWF often occurs are lower than those present in dental hand instruments. Experimental investigations demonstrate that VWF may result from these low frequencies.

The vibration exposure of dentists is determined according to European legislation as the risk of frequent finger symptoms of dentists. The use of dental handpieces exposes the dental personnel to high–frequency vibration. The vibration of dental handpieces is powerful in the frequency range above 1250 Hz. The daily exposure action value for hand–arm vibration shall be 2.5 m/s², according to European Community directive vibration. Dentists have a high frequency of upper limb symptoms. Dentists have a high prevalence of osteoarthritis in the distal interphalangeal joints. The vibration exposure in dentistry is a risk factor for the development of neurological and circulatory disturbances in the hands and related hand symptoms. There is a relationship between vibration and musculoskeletal symptoms because musculoskeletal symptoms may increase with the use or ultrasonic and/or manual instruments.

In this paper, we investigate stages of processing in a dental laboratory by means of analyze of noise and mechanical vibrations. The experimental investigations allow us to assess the exposure to noise and vibration of the worker. The research allow you to identify the stages of processing more harmful to the health of the worker. The exposure of the worker is evaluated by means of the cross–correlation of the noise and of the accelerations in the time domain and in the frequency domain.

2 Methods

Eight healthy volunteers with at least 10 years in clinical dentistry agreed to participate in the study. All subjects are working in hospital 36/38 hours per week. No one of them has a family history of Raynaud’s phenomenon. All are right–handed. Peaks of acceleration depend on age and body mass index. The examinations are performed in a laboratory with a temperature of 23 ± 1° C. Skin temperature is measured at the palmar surface of the fingers before the tests is started. To acquire mechanical vibrations we utilize the capture card with 4 channels for sound and vibration applications. The card is small and allows the measurement of levels of vibration acceleration on three axes X, Y, Z and acceleration combined with frequency analysis in 1/3 octave band and FFT. The card allows us the measurement of the noise levels in the time and frequency domain by means
of a 3-axis accelerometer (ICP) and microphone.

The current international standard for evaluating hand–transmitted vibration is ISO 5349-1 2001. The international standard suggests how the severity of exposures to vibration depends on the magnitude, frequency, direction and duration of vibration. Acute exposures to vibration provoke vasoconstriction in the fingers of the vibrated hand and in fingers on the hand exposed to vibration. The vascular response during and after exposure dependent on the magnitude and the frequency of the vibratory stimulus. The surveys were performed in accordance with ISO 5349-1 in 2001 from which it derives the name of the axes, namely: X–axis orthogonal to the palm of hand; Z–axis parallel to the bones of the forearm; Y–axis parallel to the palm of the hand and perpendicular to the Z axis.

We propose experimental investigation of different processes, analyzing noise and vibration. The experimental investigations allow us to assess the exposure to noise and vibration of the worker. The experimental investigations allow you to identify the stages of processing more harmful to the health of the worker. In dental laboratories, the noise is mostly caused by grinding, cutting and polishing operations and exhaust ventilation. It is discontinuous and wide–band, but often with predomination of high–frequencies. The noise exceeds the action levels for harmful noise during cutting and grinding metal surfaces and plaster casts.

3 Results

The transfer of mechanical vibrations from the equipment to the human body can provoke danger on the human body. The vibrations are acquired both directly at the point of application and indirectly through the whole body of the operator. The negative effect of vibration on the human body depends on the following aspects: intensity of vibrations, range of frequency, direction, type, point or penetration, time and kind of daily exposure and the total time of exposure. Dentists and dental technicians work together. Dental technicians create the model of the patient’s mouth or teeth in order to product a nearly exact replica of the lost tooth or teeth. Dental technicians can perform in five areas: orthodontic appliances, crowns and bridges, complete dentures, partial dentures or ceramics. This work is very important and time consuming. Technicians and dentists working in hospital, usually perform 36/38 hours a week, but, self–employed technicians frequently work longer hours. They are exposed to hand/arm vibrations because they have to use different appliances and hand/held tools.

The most part of dentists (≈ 70%) can have symptoms localized to the dominant hand. A little part of dentists (≈ 10%) can have bilateral symptoms. None had symptoms in the nondominant hand. The symptoms descriptions included tingling, numbness or reduced sensibility, and reduced manipulative dexterity. In most cases, the symptoms could not be localized exclusively to median or ulnar innervated skin areas. Dentists and technicians make use of high-speed rotating handpieces with a grip involving only the first three fingers of the dominant hand. Vibration at frequencies above 150–200 Hz tends to be isolated to areas of the hands and fingers directly in contact with the vibrating tool, and any adverse effect of high frequency vibration should be limited to the structures in direct contact with the instruments. At low frequencies, there is a work related sensitivity disturbance and it is an early sign of the hand–arm vibration syndrome. The most part of dentists and technicians (≈ 80%) are smokers.
3.1 Processing of ceramic structures

The final structure of a capsule is composed by two layers, an internal reinforcement mesh, and an outer layer of ceramic (Fig.1). It takes a drill with a maximum capacity of 40000 rev/1'. The drill consists of miniaturized electric micromotors (Fig.2).

The turbines are tools at very high speed with a large cutting capacity. The turbines allow you to perform the processing of ceramic structures quickly and with high precision cutting. In the workplace an exhaust system is needed to pick the fine particles of the preparation of ceramics. The air cleaner for fine particles is an integral part of the work bench to protect the worker. The processing time is about 10–20 minutes. During this process the noise reaches peaks of 80 dB in the time domain (Fig.3)
3.2 Processing of metal structures

In general, the metal structures of a bridge present a thin extension beyond the limits of the preparation. The thin extension must be reduced (Fig.4). For aesthetic and functional reasons it is necessary to remove the nodules residues. The process is the finishing of the metal structure of a bridge, which takes place by means of a cutter. The milling cutter proceeds according to the same direction. Therefore, the stress on the hand–arm system is always in the same manner. Performed to remove of nodules residues, finishing allows to obtain a uniform degree of surface finish of the metal structure. The work will last about 10–20 minutes.

Analyzing this process in time domain, the values of acceleration reach peaks less than $2 \text{ m/s}^2$ in the direction X (Fig.5). In the Y direction the accelerations exceed values of $3.4 \text{ m/s}^2$ (Fig.6). In the direction Z (Fig.7) the values of acceleration reach peaks greater than $2 \text{ m/s}^2$. In frequency domain, high values of acceleration are acquired in the field 8-16 Hz.
Figure 5: Processing of metal structures: root mean square acceleration spectra (X-axis)

Figure 6: Processing of metal structures: root mean square acceleration spectra (Y-axis)
A suitable abrasive tool is necessary to produce the partial or total processing of a plaster model. The tools are the rotating abrasive cutting used in dentistry (Fig.8). The cutters are tools of steel or tungsten carbide provided with a primary surface, a ball or cylindrical, and a secondary one, made by the blades. The heads of the abrasive tools are made up of numerous small angular particles of hard substance, applied to a substrate of softer material. The cutting takes place by elements of hard particles, which protrude from the substrate. The elements of hard particles are in contact with the plaster model. The friction and the resistance depend on the material and the design of the cutting surface.

Examining this process in time domain, the values of acceleration reach peaks greater than \( 2.5 \, \text{ms}^{-2} \) in the direction X (Fig.9), Y (Fig.10 and Z (Fig.11). In frequency domain, high values of acceleration are acquired in the field 8-200 Hz.
In the processing of plaster models, the blades, with larger areas, enable the process of carving. By contrast, these blades increase the phenomenon of vibrations. In fact, the abrasive surface has grooves that triggers vibratory phenomena. The vibrations are harmful to the turbine and, therefore, for the hand–arm system.

Figure 9: Processing of structures in gypsum: root mean square acceleration spectra (X–axis)

Figure 10: Processing of structures in gypsum: root mean square acceleration spectra (Y–axis)
3.4 Processing by model trimmer

Model trimmer regulates the size of the model (Fig. 12). Model trimmer has a powerful motor with continuous service with a high torque. The disk rotates at 2800 rpm. The design of the structure limits the leakage of dust, sucked by a vacuum cleaner with high power. The switch starts the machine and the vacuum cleaner. Model trimmer has a diamond disc highly resistant.

In this process we acquire dangerous levels of noise (Fig. 13) and values of acceleration (Figures 14, 15 and 16) greater than those permitted by regulations regarding noise and accelerations.
Figure 13: Frequency analysis of noise generated by processing by model trimmer

Figure 14: Processing by model trimmer: root mean square acceleration spectra (X-axis)
4 Discussion

Adverse effects may occur in the upper limbs, especially when the hands are holding the instruments. Vibrations on the upper limbs cause changes in the vascular, neural and osteoarticular systems. Exposure to vibrations may cause an occupational disease named the vibration syndrome. Its most common variety is the vascular form, but it also appears in a neural and osteoarticular
form. If the temperature of the environment falls, hypersensitivity to cold occurs as well as paroxysmal blanching of one or more fingertips. Paroxysmal circulatory disturbances in the fingertips are described as Reynaud’s phenomenon, dead fingers or the white finger syndrome. Vibration syndrome causes numbness and tingling in the fingers and hands. Neurosensory, vascular and osseous changes may occur independently. Changes in the osteoarticular system of the hand arise mainly as a result of local vibrations at frequencies below 30 Hz. The dynamics of the changes happening in the course of occupational exposure to vibration is usually slow and no acute pains. Deformations of articular spaces, changes in the periosteum and in the osseous texture represent the dynamics of the changes. The negative effect of local vibrations occurs within the range 5–1400 Hz. The most harmful are low–frequency vibrations, i.e. those below 16 Hz. Moving parts of the various machines, operating at the dentist’s workplace, provoke local vibrations. The main source are vibrating power–driven or air–driven instruments, such as low- and high–speed handpieces as well as ultrasonic instruments. The vibrations, emitted by these machines, are transmitted directly from the handles to the operator’s hand. Decreasing in noise and vibration levels are obtained by minimizing clearance, unbalance and the collision of moving parts in the dental machines.

5 Conclusions

Dentists exposed to high–speed rotating handpieces for many years have a high frequency of neurological symptoms, especially in the dominant hand. The symptoms are comparable to those described in the hand–arm system. Regular exposure to the vibration of hand, using held powered tools, can result in a disorder in the fingers named vibration induced white finger. The different mechanisms that can disrupt finger blood flow during and after exposure to vibration are central sympathetic reflex mechanisms locally mediated mechanisms, or a combination of both.

References


