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Acoustic Trauma Potential from Exposure to High Speed Drills in the Guinea Pig

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ACOUSTIC TRAUMA POTENTIAL FROM
EXPOSURE TO HIGH SPEED DRILLS
IN THE GUINEA PIG

BY

Peter J. Couri

A Thesis Submitted to the Faculty of the Graduate School
of Loyola University of Chicago in Partial Fulfillment
of the Requirements for the Degree of

Master of Science

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VITA

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In June, 1978, he was married to Barbara Kathleen Brown.

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INTRODUCTION

With the advent of high speed drill equipment in the mid-1950's, the dental community has been concerned ever since with the irritating high frequency sounds emitted by such equipment. Many studies have been undertaken to measure the intensity and frequency of the high speed drill sound. These factors were then related to experiments which dealt with the length and continuity of the dentist's exposure to the sound.

It is the purpose of this investigation to measure the exact effects high speed drill sounds have on the hearing mechanism of the guinea pig. Calibrations and examinations will be made to measure if any temporary threshold shifts and/or permanent threshold shifts will be present in any of the animals after various exposures to the high speed drill sounds. The parameters of continuous exposure and intermittent exposure will be considered. Histologic studies will then be undertaken on the guinea pig cochlea for any indications of possible hearing damage.

It is hoped a standard can be established as to what time periods of exposure to high speed drill sounds will be needed to produce a hearing threshold shift, whether continuity and intermittency are detrimental factors, and if these exposures will cause permanent injury to the cochlear structures.

REVIEW OF THE LITERATURE

Sustained loud noise in any environmental situation poses a potential health hazard. The present day urbanized environment in which we live abounds in agents which constitute an ever present threat to hearing. Dentistry, like every other profession, never has been so sound and noise conscious as it is today.

Kessler (1961) points out that noise can affect both physical health and work efficiency. Excessive noise can produce temporary or permanent hearing loss, disturbances in equilibrium, and other disagreeable experiences. Davis (1958) argues that when the threshold of hearing reaches a certain critical level, man can no longer perform his duty and a small additional loss of hearing would bring with it additional handicap. Kessler (1960) indicates that loss of eyesight is considered a major disability for dentists, but hearing loss is not as disabling and consequently does not hinder the normal practice of dentistry. However, hearing impairment can and often does result in confusion, fear, and loneliness. He states, "Loneliness can exist even though a dentist sees a normal schedule of patients as well as his family and friends. He feels cut off from the outside world; first, within the walls of his dental office, and then within the walls of himself, thus impairing his efficiency".

Industry has used high rotational speed equipment for many years, but it was not until the late nineteen thirties and early forties that the dental profession realized that diamond cutting tools perform better at speeds

higher than 1000 to 2000 revolutions per second. Terranova (1967) traces the development by dental equipment manufacturers of high-speed equipment to 1954, with full scale production commencing around 1957. He points out that even though the high speed drill had the disadvantages of a high original cost, costly maintenance, and reduced field visibility, the dentist's chief concern was the irritating sound resulting from ultra-speed equipment. Thus, scientists began to investigate the possibility of auditory damage to dentists resulting from the use of the high speed air turbine.

It is generally accepted that there are five major factors investigators must take into consideration when they are studying the damaging effect of noise or acoustic trauma. They are: (1) the intensity or loudness of the noise; (2) the frequency component (pitch) of the noise; (3) the length of exposure; (4) the continuity of the exposure; and (5) the susceptibility of the person exposed, that is, his age and physical status of his hearing apparatus.

A. INTENSITY

The intensity or noise level is a primary factor for estimating the damaging effects resulting from acoustic trauma. Glorig (1959) compiled a study of injurious noise levels and which levels constituted the borderline between innocuous and injurious intensity levels. He found that in the United States and Japan, injurious noise is initiated at 90 decibels at 2000 to 3000 cycles per second, and 85 decibels at 3000 to 6400 cycles

per second. Russian studies indicate injurious noise levels to be between 75 and 85 decibels for all frequencies between 800 to 12,000 cycles per second.

Maximum noise level studies deemed safe in the 5 to 10,000 cycles per second range have been reported by various investigators in the 1950's. Hardy (1952) estimated the ear could withstand a constant exposure to 95 decibels at these high frequency levels. The United States Air Force medical service branch in 1956 recommended the use of ear protection if noise exceeds 85 to 95 decibels in this frequency range. Kylin (1959), derived a damage risk curve using the amount of temporary threshold shift caused by a damaging noise, and from this determined the maximum safe level to be 83 decibels. Kryter (1962) estimated for an eight hour per day working lifetime exposure, the maximum safe noise level for sound above 5000 cycles per second should not be greater than 81 decibels.

In a symposium on occupational hearing loss noise, Fox (1972) announced exposures which were considered permissible by the Occupational Safety and Health Act established by the United States Department of Labor (c.f. table I). He points out that "prior to the establishment of the OSHA regulations, only a handful of state agencies had any guidelines which specified hazardous noise exposure. Today, first priority is given to feasible engineering or administrative measures to reduce exposure to safe levels."

Miller (1974) found that in general A-weighted sound levels must exceed 60 to 80 decibels before a typical person will experience temporary

Table I
PERMISSIBLE NOISE EXPOSURES

Sound level (decibels)	Duration per day (hours)
90	eight
92	six
95	four
97	three
100	two
102	one and one half
105	one
110	one half
115	one fourth or less

Occupational Safety And Health Act
Meyer S. Fox-Laryngoscope 82:1226, 1972.

thresholds shifts even for exposures that last as long as 8 to 24 hours. He cites evidence that noises of approximately 80 decibels for two days produce only small temporary threshold shifts that do not completely disappear for several days. Miller states that sound levels above 80 decibels can contribute to inner ear damage and eventual hearing handicap if these noises are frequently and regularly encountered. Martin (1975) reported increased risk of noise induced hearing loss at noise exposure levels between 85 and 90 decibels. This risk increases ranges from 4 to 22 5/10 percent for subjects 50 to 65 years of age.

Since the question of danger to hearing concerning high speed handpieces arose, many studies have been undertaken to determine the level of the noise intensity of the high speed dental drills. In a study on two types of ultra speed handpieces, Cantwell (1960) reported that several air turbine handpieces of the same make produced noise levels above 84 decibels in the range of 5000 to 9000 cycles per second. Robin (1960) recorded the intensities of four different models of high speeds and found the level of noise to be 80 decibels for two of them and 60 decibels for the remaining two. The distance from the handpiece to the noise level indicator was 12 inches. This is considered to be the average distance between the dentist's ear and the patient's tooth. Marrant (1960) measured the sound intensity of a number of handpieces and reported the intensity to be between 80 and 83 decibels. Again the distance between the handpieces and the condenser microphone was 12 inches.

Noise level measurements were taken by Weston (1962) at the dentist's

ear level during cavity preparation for patients, on extracted teeth, and while freely running without drilling. This was done with the various types of drills available, including Australian, American, German, and British handpieces. Weston found the overall decibel level to be 74 to 88 decibels. He also determined that the overall decibel emission from the American and British drills to be 84 decibels while the German and Australian handpieces gave out 82 decibels overall.

Hopp (1962) measured the noise levels of the handpieces used at the University of California Dental School (three different types), and found the intensities to be 85 to 90 decibels for one, 80 to 85 decibels for the second, and 95 to 100 decibels for the third. These decibel levels convinced him that the high speed handpiece is capable of producing acoustic trauma. The National Naval Medical Center (1962) measured the noise levels of their air turbine drills and found the overall range to be 85 to 93 decibels.

Penn (1963) collected intensity data while operating a drill inside the mouth, outside the mouth on extracted teeth, and on glass. In drilling on tooth structure in the mouth, the decibel level reached 92 decibels for four patients. Drilling on extracted teeth produced a noise level of 97 decibels while the glass study yielded a 99 decibel level.

Kessler (1964) reported noise levels from 75 to 104 decibels at a distance of 6 inches when air turbine handpieces were operated at maximum speeds. Cantwell (1965) found his turbine handpieces with air bearings to have noise levels of less than 68 decibels (free running) at 40

to 60 pounds of air pressure. Cooperman (1965) conducted a noise level survey of sixteen dental handpieces from various manufacturers. The overall noise levels, measured at 24 inches, ranged between 72 and 84 decibels. He indicated these levels border on or exceeded the accepted levels of risk for noise-induced permanent hearing impairment.

Taylor (1965) evaluated the overall sound pressure levels and octave band range of a number of air turbine drills in dental offices and in hospitals. He reported the levels of noise to slightly above 85 decibels overall, fluctuating from 75 to 100 decibels. Applying these levels to the damage risk criteria, he found one drill of the old type exceeding this limit, the others at or near this limit, and the latest air bearing type falling safely within the non-hazard zone. He concluded that there was no hazard to dental practitioners exposed to air turbine drill noise. Kryter (1966) found the intensity of the drills in his study to reach a level of 85 decibels, but he specified the level as hazardous by damage risk criteria for steady exposures.

B. FREQUENCY

The frequency of a noise also is a critical factor when acoustic trauma is considered. It has been well established that hearing for frequencies above 3000 cycles per second, particularly between 4000 and 6000, is much more vulnerable to persistent noise induced hearing loss than is hearing for the lower frequencies (Davis, 1958; Robin, 1960; Hopp, 1962; Terranova, 1967). Miller (1974) found noises with energy concentrations

between 2000 and 6000 Hertz produce greater temporary threshold shifts than noises concentrated elsewhere in the audible range.

Sound analysis studies have been reported of the frequencies for high speed handpieces of all manufacturers. Noise from air turbines was measured free running at ultra speed by Marrant (1960), Holden (1962), and Ward (1969) and found to lie in the high frequency range of above 4000 cycles per second. The National Naval Medical Center (1962) revealed their highest noise levels were in octave bands 2400 to 4800 cycles per second. Robin (1960) measured four different models and found the frequencies to be 5500, 4000, and 2400 cycles per second free running. Hopp (1962) reported that the air turbines transmitted at wavelengths close to 5000 cycles per second. Schubert (1963) reviewing the results published by Cantwell (1960), Hartley (1959), and Rademacher (1961), compared their high frequency measurements and found them all to be above 5000 cycles per second. Sockwell (1971) produced frequency ranges between 3900 and 5700 cycles per second with his free running air turbines. When he applied a cutting action, the frequency rose to 7500 cycles per second.

Noise levels of sixteen high speed handpieces were reported by Cooperman (1965). For three belt driven hand pieces, the frequency fell between 2000 and 3000 cycles per second. For the thirteen air operated high speeds, the reported frequency was approximately 4800 cycles per second with some reaching as high as 6000.

Penn (1963) gathered frequency data on high speed drills performing

inside the patient's mouth, on extracted teeth, and on glass. His studies revealed a frequency of 1400 to 4000 cycles per second in the patient's mouth, 4800 on extracted teeth, and 1700 when drilling on glass. An extremely high decibel level was emitted when executed on the glass. Penn superimposed the frequency of the sound produced by the drilling on patients with the "Frequency Curve of a Hearing Damage Risk Chart for Human Exposure to Noise" (Miller, 1959). He noted that sound peak frequencies were significant in the hearing loss area.

Investigators have also found that the higher the frequency of the tone, the nearer to the round window is the site of hearing loss (Lurie, 1944). Davis (1957), working with the guinea pig, found that the injury caused by 8000 cycles per second was centered in the basal turn of the cochlea, at 2000 cycles per second in the second turn, and at 500 and 185 cycles per second in the third and fourth turns. He found no pure tone, at the intensities and durations employed in the study, injured all sections of the cochlea.

C. LENGTH OF EXPOSURE

The length of exposure also is a critical factor in assaying acoustical trauma. It must be considered in connection with the other four factors (i.e. intensity level, frequency level, continuity of exposure, and susceptibility). As a general rule, the longer the exposure, the more likelihood the danger of damaging effect (Robin 1960). Miller (1963) looked at the effects of noise on 42 trained cats. Among other results, he found that an increase in the duration of exposure to continuous broad

band noise correlated well with an increase in the amount and the extent of permanent hearing loss. Spoendlin (1973) exposed one-hundred guinea pigs to a wide band noise at intensities between 110 and 140 decibels with exposure times varying between 30 seconds and one week. He discovered that exposure time and intensity do not seem to be equally responsible for structural damage. At higher intensity levels, exposure time is a more deciding factor as to the extent of damage than is exposure intensity.

Kryter (1973) suggested that there is an equivalence in the growth of temporary and permanent threshold shift as a function of the duration of single continuous exposures. For each doubling of time, there was a 6 decibel increase in temporary threshold shift and eventually, he hypothesized, a similar increase in permanent threshold shift keeping other factors constant. In relating the growth of hearing impairment with years of exposure, he postulated that doubling the number of years of exposure from a given base year will cause an increase of 6 decibels in permanent threshold shift provided the daily noise-exposure condition is kept constant.

In one of the few hearing experiments involving man, Mills (1970) measured the effects of long noise exposure (two days) on a single subject. The study indicated that hearing sensitivity will decrease with duration up to a maximum and then no further decrease will result. The temporary threshold shift of his subject was asymptomatic following the first 8 to 12 hours of noise exposure. Melnick (1974) accumulated data using ten subjects that indicated for exposures to noises above 1800 Hertz, the

temporary threshold shift will be asymptomatic after 240 to 480 minutes of exposure. For exposure to noises less than 1800 Hertz, durations longer than 480 minutes were needed to produce asymptomatic temporary threshold shift. His subjects also were tested at the 80 to 90 decibel level at 125 to 8000 Hertz for 16 hours. The group data indicated that the 16 hour exposure period was not long enough to clearly establish asymptomatic levels of temporary threshold shift. All the subjects recovered to within 5 decibels of the pre-exposure threshold levels 59 hours post exposure.

The length of exposure and its effects in regard to high speed dental drills were investigated very soon after they were in general use. Fisch (1957) investigated the pneumatic drills of 95 decibel intensity and concluded that it is conceivable that some individuals exposed for many hours each day to this noise for several years would suffer damage to their hearing, some to such a degree that hearing for speech in everyday life would be seriously affected. Bernier (1959) subjected six members of the dental staff of the Armed Forces Institute of Pathology to 3 days of drill noise exposure. The first day, they were subjected to 7 minutes of noise each hour for 8 consecutive hours, and then 15 minutes each hour for 8 hours on the second and third days. While they demonstrated no significant threshold shifts, there were some individual shifts which they felt warranted further research so as to determine the amount of danger to the hearing mechanism. Marrant (1960) presented evidence that indicated that the sound pressure levels of the air-turbine

frequencies might approach the borderline of safety if the operator were subjected to this noise continuously during the working days for a number of years.

Cantwell (1960) estimated the general dentist used the high speed drill 12 minutes per day, or one hour a week. Kessler (1961) gave the view that although many authorities calculated the length of time the average dentist uses his air turbine handpiece is so short that he does not have to worry, it would be a good practice for dentists to have audiometric checkups at regular intervals. Davis (1961) computed that when drill exposure totals 15 minutes within 2 hours, the maximum safe level is 95 decibels. Analyses of noise measurements performed by the National Naval Medical Center (1962) indicate that repeated daily exposure of less than 150 minutes to the high speed drill was within permissible limits and should not constitute a hazard to hearing. Weston (1962) found the average dentist was exposed to the actual drill noise for a total time of no more than one hour per day. At these levels, he concluded drill noise would not be expected to have any serious effect on hearing acuity of "average" ears. He states though that his conclusions were not definitive.

Penn (1963) established that a dentist spends at least an accumulated 30 minutes drilling per day, and if above the 85 decibel intensity, injury could result depending on the nature and duration of exposure. Schubert (1963) prepared a detailed study of a drill use schedule (c.f. table II). With an average time utilization of 12 minutes daily, he suggested the

Table II

Characteristics of a drill use schedule for one dentist

No. days record kept	58
No. patients seen.	293
No. surfaces worked on	744
Average operating time per patient	1.97 min.
Average operating time per surface	0.97 min.
Average time drill was on per day	12.4 min.
No. individual noise exposures per day	58

Schubert, E. "Noise Exposure from Dental Drills."
J.A.D.A. 66:751, 1963

noise from a drill could be as high as 101 decibels and still not cause permanent elevation of the auditory threshold at frequencies 6000 cycles per second. To determine this, he used the maximum safe exposure level data set forth by the United States Air Force Medical Service (1959). See Figure 1. Their data utilized what is sometimes called the equal energy rule. The rule states that every time the exposure time is cut in half, the maximum safe level may be raised by 3 decibels; in effect doubling the intensity. Schubert made a call for more general data on time distribution characteristics of individual drill noise exposures.

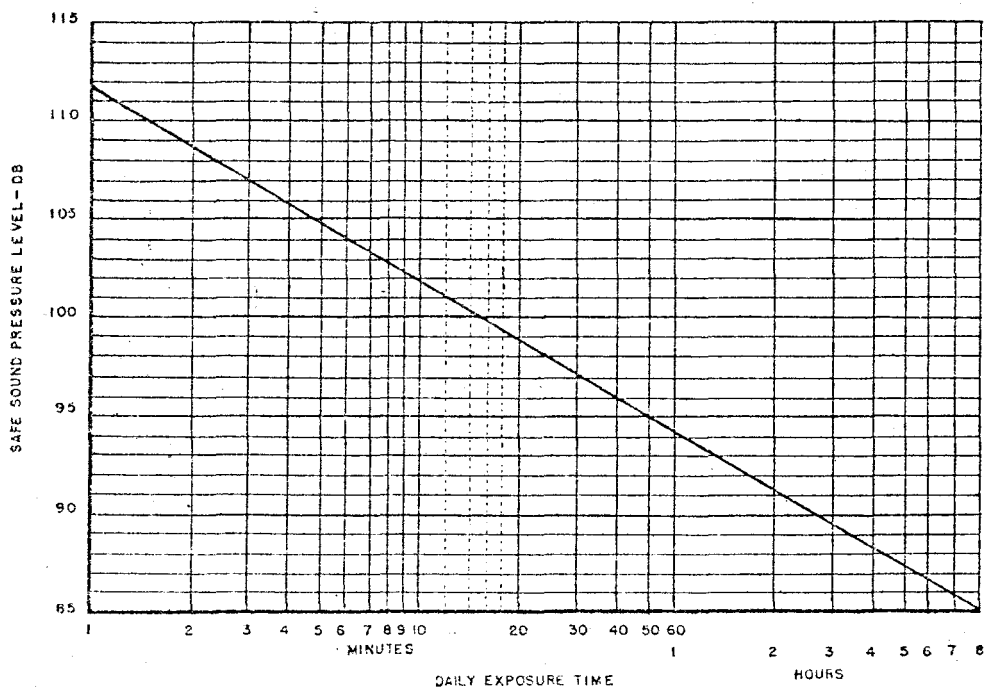
Gelb (1965) examined a study of hearing losses in airline pilots. The study showed that exposure to noise in the order of 1000 hours produced significant hearing losses. He concluded that it was logical to assume that some dental exposures similar in nature and duration to that experienced by the airline pilots would have the same end-results. Estimates of exposure time were collected by Taylor (1965) showed large variations from a half hour to 4 hours per day, with one accurate taped recording of 55 minutes of drill noise. He concluded that noise-induced threshold shifts will increase with increasing exposure time, and that a case can be made for a hearing conservation program for all practitioners using high speed instrumentation. Dellheim (1971) and Sockwell (1971) both reported exposure times from 12 to 45 minutes per day. Sockwell went on to state that "while 12 minutes may be a fair average for the general practitioner, there are a number of dentists who practice mostly operative or crown-and-bridge procedures and their exposure time easily could double or triple this estimate."

Figure 1

Maximum safe exposure levels for daily exposures of less than 8 hours.

The limits between the 10 and 20 minute points of the abscissa represent 12, 14, 16, and 18 minutes respectively.

Fig. 2 • Maximum safe exposure levels for daily exposures of less than eight hours. The lines between the 10 and 20 minute points on the abscissa represent 12, 14, 16 and 18 minutes, respectively



Schubert, E. "Noise Exposure from Dental Drills".
J.A.D.A. 66:751, 1963

D. CONTINUOUS vs. INTERMITTENT EXPOSURE

Another criteria for evaluating acoustic trauma is whether the noise being considered is of a continuous or intermittent nature. When one experiences exposure to a loud noise, his ears sometimes ring and other voices may sound muffled, but the hearing returns to normal within a few hours or possibly days. The recovery is generally complete and may be considered a fatiguing type of hearing loss rather than an injury. Gelb (1965) points out though that at some point this temporary hearing loss called fatigue could initiate permanent injury. Sockwell (1971) asserted that when one is subjected to a loud noise of short duration, a protective reflex of the ear causes it to lose some sensitivity temporarily. This is, in effect, a temporary threshold shift. He compares it to the fatiguing effect of the olfactory nerve whereby odor becomes less noticeable after a short period of exposure. "If sufficient time is allowed between exposures, recovery will be complete. If exposure to a noise has been intense for a long period of time without sufficient recovery periods, a persistent threshold shift occurs which could result in a permanent threshold shift." He goes on to explain that higher noise levels can be tolerated if there are sufficient recovery periods. Robin (1960) asserted that the ear can tolerate without damage a single loud noise up to 130 decibels, but "repetitive insults" at this or any other injurious level is likely to cause damage if rest intervals are not given. He determined that the length of the rest periods necessary to obtain a return of normal hearing will differ with various factors (especially the susceptibility of the individual) and would

have to be determined for each case.

Robin (1952) in another study found minor degrees of hearing loss, such as 20 decibels, showed complete recovery in a few days or at least a few weeks if no further exposure to the noise is experienced. Larsen (1953) studying riveters found that although intensity levels were as high as 120 decibels, considerable recovery took place within a few hours after work. Taylor (1965) studied the noise exposures of jute weavers who had worked in the mills for one to 52 years. All of the subjects were women and had little exposure to loud noise other than that received on the job. Since the noise of the mill had a noise level of 90 decibels, Taylor expected the 8 hour working day to produce a 35 to 65 decibel temporary threshold shift at 4000 cycles per second. After 2 days, which would be a weekend for the workers, the threshold shift would be expected to recover to within 5 decibels of the normal. Taylor found, however, that as exposures were repeated year after year (5 days a week, 50 weeks a year), the ear became less and less able to recover from the temporary threshold shift present at the end of each day. As the exposures were repeated, the noise induced temporary threshold shift became permanent.

Lipscomb (1969) exposed guinea pigs to a continuous tape loop of noise and concluded that at high level noise exposures, short rest periods are essential to minimize the damage to the cochlea. Rintelmann (1968), investigated the effect of rock and roll music at a 92 decibel level, wrote "rock and roll music is intermittent, with an on-time of approximately three to five minutes and with a very brief off-time of usually less than

one minute. Even this very short off-time, however, is apparently sufficient to allow at least partial recovery from auditory fatigue."

Smitley (1971) compared the temporary threshold shift of subjects exposed to 60 minutes of rock and roll music played continuously with the mean temporary threshold shift of subjects exposed to 60 minutes of the same stimuli and intensity level played intermittently. Her results showed a significant difference in the temporary threshold shift between continuous and intermittent exposure conditions with greater shifts resulting from continuous exposure at 250, 500, 2000, and 3000 cycles per second. At 4000 to 8000 cycles per second, significant differences were not noted. Smitley concluded that at these high frequencies individuals may be susceptible to temporary threshold shifts whether the stimulus be continuous or intermittent. 65 to 70 percent of the subjects exposed to both continuous and intermittent noise had the same threshold shift at 4000 cycles per second. Below 4000, continuous exposure was harmful to nearly 50 percent of the subjects while intermittent exposure was unsafe for 25 percent of the subjects. It was apparent that rest periods have some effect upon the rate of recovery of the temporary threshold shifts.

Kryter (1966) found that as far as permanent impairment to hearing is concerned, intermittency is the major factor that makes tolerable sounds and noise in excess of 55 decibels. He found that for each doubling of time following 2 minutes exposure, there is a 3 decibel recovery in the temporary threshold shift. Miller (1970) discovered people could tolerate many brief exposures in excess of 70 to 80 decibels if they are

widely spaced in time. He gives the example of a shower bath. A shower has a sound level of 74 decibels and one would have to shower for over an hour before a temporary threshold shift would appear.

The dentist's exposure to the high speed handpiece noise is definitely an intermittent situation. Marrant (1960) clearly observed that intermittent exposure to the noise levels of air turbine handpieces obviously reduces the risk of acoustic trauma. Kessler (1960) declares that only when exposure to drill noise is prolonged and repeated at frequent intervals can hearing damage begin to occur for the dentist. Schubert (1960) noted that as long as the use of the high speed drill is so intermittent, the sound would have to be of a higher level to be damaging. Robin (1960) found that loud noise interrupted several times a minute had a worse effect than continuous noise of the same intensity. He cautions dentists that this nuisance effect may gradually cause permanent cochlear damage. Ward (1969) examined the damage-risk criteria levels measured for the dentist's situation with the high speed drill. He concluded that due to the intermittency of the dentist's exposure, levels of at least ten decibels higher can be measured for a safe level of intensity from the high speed.

E. SUSCEPTIBILITY

The susceptibility of persons exposed to noise seems to vary tremendously. Melnick (1974) pointed out that one of the enigmas about hearing loss produced by noise exposure is that people with apparently similar histories of experience with noise do not necessarily develop

similar hearing loss. A study by Miller (1974) indicated that people differ in their susceptibility to temporary threshold shifts and these differences are not uniform across the audible range of frequencies. One person may be especially susceptible to noises of low pitch, another to noises of medium pitch, and another to noises of high pitch. Ewertsen (1973), in his study of the noise industries in Denmark, found hearing impairment to be slowly progressive and to be irreversible, but stated that "the individual's susceptibility to noise-induced hearing loss cannot be predicted".

Bredberg and Hunter-Duvar (1973), reviewing the literature of behavioral tests of hearing and inner ear damage, point out the problem of subject variability in hearing experimentation. With both humans and animals, the ototoxic stimulus that may result in a severe permanent threshold change in another. They further elucidate that this high subject variability seriously restricts the usefulness of statistical measurements and contributes significantly to the diversity seen when the results of different studies are compared. Davis (1958) examined the hearing loss standards prepared by the Air Force and suggested that such regulations are statistical in nature and are designed to cover the large majority. He concluded that individuals definitely differ in their susceptibility to noise induced hearing loss.

Ward (1965) reviewed the concept of susceptibility to hearing loss following continuous noise exposure and concluded that susceptibility was normally distributed in a population. Kryter (1965) exposed subjects

to impulses ranging in intensity from 160 to 170 decibels and found that the temporary threshold shift was distributed bimodally across subjects. These two ranges of temporary threshold shift were found to actually be a reflection of "tough" and "tender" ears. They suggested that this dichotomy might reflect either invariant differences in different ears or a threshold effect in a given ear. Hamernik (1974), studying histological susceptibility to high intensity impulse noise, found extreme variability in total hair cell losses of the organ of Corti in twelve guinea pigs. He suggests that a comparison across animals exposed to high levels of impulse noise must be made with caution and that the mediating effects of unknown intensity-related variables must first be considered.

Smitly (1971) presented a study of subjects exposed to sixty minutes of rock and roll music both continuously and intermittently. Inspection of their data showed considerable variability from subject to subject in the absolute amount of temporary threshold shift, especially at the high frequencies. At 3000 to 4000 cycles per second, individuals varied as much as 50 decibels in the resulting temporary threshold shift. These large differences proved to them that individuals vary considerably in susceptibility to this type of exposure.

With advancing age, people almost uniformly experience increasing difficulty in hearing. Undoubtedly, some of this loss is due to the degeneration of neurons in the brain which generally accompanies advancing age. Ewertsen (1973) stated that in a person with noise induced hearing

loss, this loss will be added to that attributed to aging. He stated, "It is, therefore, usual for people with occupational hearing losses to get along quite well through their thirties and forties, until they come to the age of fifty years, when they begin to feel their hearing handicap more and more. This means that the noise wears out the reserves 10 to 20 years earlier than we would have expected due to aging". Miller (1974) also suggests that a small loss of hearing from exposure to noise may be insignificant when one is middle-aged, but might, when combined with other losses due to age, become significant as one reaches advanced age. Davis (1957) in his exercise on the biophysics of the inner ear notes that noise induced hearing loss and advanced age hearing loss are independent, but additive.

Forman-Franco (1978) compared the hearing levels as adjusted for age of the general population to the hearing levels of general practitioners and found no statistical differences. She concluded, "a correlation appears to exist between years in dental practice and progressive loss of hearing. However, this mimics the relationship of advancing age and loss of hearing in the normal population and suggests that when a loss of hearing occurred, it was primarily an affect of aging.

Robin (1960) noted that in addition to age susceptibility, persons who are debilitated and tired are most sensitive to hearing loss, as well as persons with certain ear conditions, such as otosclerosis, nerve deafness, etc.

In his investigation of age and sex differences in pure tone thresholds, Corso (1959) reported that women have more sensitive hearing than

men and show less intersubject variability. This sex difference was independent of age and was more marked at the higher frequencies. For both men and women, there was a decrease in hearing sensitivity with increasing age and a progressive spreading of the loss from the higher to the lower frequencies. Men were shown to be more affected than women, showing a greater degree of auditory impairment. Miller (1974) found that women were less susceptible to temporary threshold shifts from low frequency noises than were men, and that this revelation is reversed for high frequency noises. Smitley (1971) could produce no significant difference between the mean temporary threshold shifts of men and women in his study of continuous and intermittent rock music.

F. DENTAL INVESTIGATIONS

Using the five factors considered to be consequential for acoustic trauma, investigators through the years have designed experiments which inquired into the hazards of the high speed handpieces using individuals and groups. Early in 1960, Brenman placed electrodes on the round window of a group of specially anesthetized cats and recorded their cochlear microphonics and neural responses. The high speed air turbines were placed fourteen inches from the ear of the animals. The auditory responses were recorded at selected times after the exposure. The animal experiments indicated an alteration in the cochlear microphonics and in the neural responses of the animals exposed to these instruments. He also obtained audiograms from human volunteers who were exposed to a controlled amount of the noise. The humans exhibited audiograms with a dip in the 4000 to

6000 cycle frequency range after an exposure to the high speed handpiece. Rapp (1960) studied the physiological responses to high speed handpiece sounds. He found that handpiece noise increased spontaneous activity in rats from 14 to 160 motions per hour and human hand reflex time to sight was increased by 38 percent during 20 minutes exposure. He further reported that skilled dentists made 10 times as many errors when asked to trace a test pattern. 10 of his 14 subjects exhibited an average rise of 28 mm Hg systolic blood pressure while exposed to handpiece noise.

Hopp (1962) performed audiograms on 61 sophomore dental students during the first 23 weeks of their exposure to high speed drills. He found no statistically significant auditory threshold drops in their audiograms due to instrument noise.

Taylor (1964) performed hearing tests on 40 dental practitioners in Scotland using pure-tone air conduction audiometry in a special quiet chamber. His results showed that after 3 to 4 years use of the drill, the dentists were beginning to show hearing defects in the 4000 to 6000 audiogram regions. In 1965, he compared these audiograms of the same 40 dentists exposed to the drill noise from one to 5 years with a matched control group of 11 dentists who had never been exposed to the high speed drill and 29 male teachers who likewise had not been exposed. Significant noise-induced threshold shifts were seen in the hearing of the exposed group when compared with the controls, at 4000 to 6000 cycles per second. He could find no differences between the groups at 3000 cycles per second or less.

Bulteau and Skurr (1965) performed pure tone Bekesy audiograms on 56 third year male dental students before exposure to high speed drill noise for the first time as operators. From this baseline, their hearing was checked for the next 2 years. For controls, 50 fifth year medical students had similar audiograms taken. By 1969 (Skurr, 1970), the dental students had been exposed to high speed drill noise to a total hour accumulation between 100 and 200 hours per student. In 1967, 12 per cent of the dental students showed a hearing loss of 15 decibels or more at 4000 cycles per second. In 1969, however, 59 per cent of the dental students exhibited a loss of at least 15 decibels. Students who presented hearing impairment at the start of the study suffered further deterioration (to at least a 30 decibel hearing loss). Skurr and Bulteau concluded that it was difficult to attribute the hearing loss to any cause other than that of high speed drill noise.

Ward (1969) conducted a cross-sectional study on 34 Minnesota dentists. All were under 60 and had no exposure to gun fire. In both his volunteers and random picked groups there was no evidence that the high-speed drills produced more than 5 to 10 decibels of loss at 6000 cycles per second. He concluded that the danger to hearing from high speed drills is very small but not completely negligible. A study by Weather-ton (1972), which lasted 3 years and involved students and staff dentists at the University of Tennessee Dental School, reported no hearing losses for the students. For the staff dentists however, there was significant noise-induced threshold change. High speed drill noise was not implicated

because the changes were attributed to age.

G. GUINEA PIG STUDIES

Experiments on hearing loss are usually done with animals because one would not deliberately deafen a human subject. For these experiments, it is necessary to train the animal subjects so that their ability to detect faint tones can be measured. The measure of this ability is the intensity level of the faintest tone that can be detected, the hearing threshold level. The greater the hearing threshold level, the poorer the ability to hear. Many investigators through the years have measured the hearing thresholds of trained animals by methods similar to those used with human patients. After the animal's normal thresholds have been measured, it is exposed to noise under controlled laboratory conditions. After cessation of the noise, changes in the animal's thresholds are measured. Subsequently, it's ears are evaluated by physiologic and anatomical methods.

Anrep (1972) reported that Pavlov in 1927 had established the practicality of using conditioned animals in auditory experimentation. He used classically conditioned dogs for his hearing loss studies and showed the animals developed a permanent behavioral hearing loss for tones lower than 310 Hertz when the apical portions of the cochleas were destroyed. Davis (1935) was the first to use conditioned behavior in conjunction with an evaluation of the histology of the cochlea. 14 guinea pigs were exposed to pure tone stimuli. Some of the guinea pigs exhibited behavioral losses of 30 decibels at the frequency of 600 Hertz with no histological

damage while others exhibited a 10 to 20 decibel behavioral loss from 4000 to 8000 Hertz with scattered missing hair cells in the first outer row of the first, second, and third turns of the cochlea.

Lurie (1944) developed important standards to categorize acoustic trauma of the organ of Corti in the guinea pig. His interest was not so much threshold levels and conditioned behavior as the exact damage inflicted upon the organ of Corti as a result of acoustic trauma. He classified the damaging lesions into 7 types in descending order of severity. The least detectable anatomical damage to the organ of Corti was the disappearance of the mesothelial cells in a limited area from the scala tympani surface of the basilar membrane. The severest damages measured were degenerative changes, rupture and dislocation of the organ of Corti from the basilar membrane.

Davis (1953) constructed an anatomical frequency scale based on the correlation between pure tone hearing loss and inner ear damage. Using 48 exposed guinea pig ears, he found injuries center in different turns of the cochlea depending on the frequency of the exposure tone. At 8000 cycles per second, the greatest injury is seen in the upper third of turn one. At 2000 cycles per second, the greatest injury is in the lower of turn two. Injury to the lower half of turn three was produced by 545 cycles per second. At the junction of turns three and four, the damage was greatest at 185 cycles per second. Both Sockwell (1969) and Pye (1971) mapped a frequency analysis pattern of the guinea pig cochlea and found that local responses up to 10,000 cycles per second can be measured

from the basal turn, up to 3000 in the second turn, and up to 5000 in the third turn.

Bredberg (1973), in a thorough review of behavior tests of hearing and inner ear damage, noted that most earlier studies used methods for testing hearing that are no longer considered reliable. Behavioral testing methods were often inadequate and conditioning of guinea pigs is very difficult yielding questionable results. He found that different species may differ greatly in their susceptibility to the same harmful stimuli. He also pointed out that histological techniques differ in the studies as do the structures that are examined. Bredberg concluded the guinea pig is unsuitable for training for the traditional forms of behavioral hearing tests such as food-reward training, respiratory cycle responses, and Preyer reflex measurements.

Guinea pigs are easy to rear, rapidly reproduce, cost little, and have anatomical features that provide easy access to the middle ear and to the cochlea. Miller (1966), in an experiment studying the threshold and habituation of the guinea pig, found the auditory sensitivity of the guinea pig is similar and just slightly inferior to man's up to 10,000 cycles per second. Unlike man, however, he found the guinea pig's upper limit of hearing extends to at least to 32,000 cycles per second. Miller emphasized in his findings the usefulness of the immobility response the guinea pig so easily adapts. Guinea pigs react to any discomfort factor by falling into a catatonic-like state so deep that a response from them is extremely hard to obtain. Miller suggested that since most hearing

experiment methods with guinea pigs are not considered reliable, appropriate experimental designs should be implemented using the immobility response as an indicator of sensory function, pattern recognition, or emotionality in the guinea pig.

Anderson and Wedenberg (1965) designed such a method using the immobility "catatonic" response. The method consists of conditioning the animal to sound by means of the well known electric sound-shock technique, making it shiver by submitting it to a sufficiently cold current of air, and causing an immediate interruption of the shiver due to pure tones between 500 and 6000 cycles per second. Shivering appeared to be a good choice for a behavioral parameter because it does not require learning by the guinea pig. Anderson was able to easily establish the normal hearing level of the guinea pigs and to evaluate its validity in the study of pathological hearing trauma.

The hearing test devised by Anderson and Wedenberg, called shiver-audiometry, was put to great use by Crifo (1973). He not only determined the minimum intensity threshold values but also found the albino guinea pig has significantly lower thresholds (better hearing) than pigmented guinea pigs. Nuttall (1974) came to the same conclusion. Crifo (1974) reported shiver-audiometry combined with morphological study of the organ of Corti is very useful in the identification of possible ototoxic properties of drugs. He recommended the method for preliminary studies of drugs before their introduction into human therapy.

MATERIALS AND METHODS

Six albino guinea pigs (Cavia porcellus) weighing 100 to 300 grams were used. Two guinea pigs were designated experimental and were subjected to continuous drill sound exposure. Two were designated experimental and were exposed to intermittent drill sounds. The remaining animals were controls.

The shiver-audiometry method originated by Anderson and Wedenberg (1965), with slight modifications, was employed. The apparatus for this procedure consisted of an audiometer (Zenith Model ZA-110TW) which generates pure tones at a frequency of 125 to 8000 cycles per second with an intensity range of 5 to 110 decibels in 5 decibel steps. It was connected to an amplifier (Knight Inc., Model IV), which in turn was led to a loud speaker (Realistic Model Solo - 4B). The loud speaker was placed at an angle of approximately 20 degrees with respect to the horizontal plane, and fixed 27 centimeters from the guinea pig's pinna. This is the estimated distance of the dentist's ear from the operating drill. The animal was held motionless by means of a box-like restraining device with its neck secured firmly in a brace. The bottom of the box was covered with a layer of ice on top of which rested a thin sheet of lead. With the animal resting on top of the lead sheet, cold was conducted easily to the animal producing a constant shiver pattern. The shiver vibrations were recorded using a pneumatic pulse transducer (Physiograph mk. III, NARCO

Instrument Co.) placed beneath the box. The corners of the box were set upon foam rubber squares in order to enable the transducer underneath it to transmit the low frequency shiver vibrations. The transducer was connected to an electrosphygmograph (NARCO Instrument Co., Inc.) which in turn was attached to a polygraph (Physiograph Four, NARCO Instrument Co., Inc., Houston, Texas) which recorded the changes in shiver amplitude. The speed control of the recording paper was set at one-half centimeter per second.

Before starting the investigation, calibration of the audiometric devices was necessary. Since the animal's head rested 12 inches from the loudspeaker, the amplifier had to be adjusted and set so that the loudspeaker emitted the sound tones to the exact level indicated by the audiometer. This was done with a decibel meter (General Electric, Model 1565A) placed at the normal location of the animal's head and the amplifier dial being turned until the decibel meter indicates the exact tone. Thus, when the audiometer was set at 10 decibels, the amplifier was adjusted until the decibel meter read 10 decibels. The ambient background noise levels measured were sufficiently low to present no interference with the experimental measurements.

Two tape recordings (Sony Superscope Model TC100) of the high speed handpiece (Starflite Titan, Model T200A, Star Dental Mfg. Co.) were created. One tape contained an uninterrupted high speed drill sound. The other tape consisted of drill sounds recorded intermittently; 1 minute of drill sound, 5 minutes of silence, 1 minute of sound, followed by another

5 minutes of silence. Each tape was 12 minutes in duration but because they were continuous loop cartridges, they could be played indefinitely. The running handpiece was placed 8 inches from the microphone when the recordings were made. The volume of the sound recorded was measured by the decibel meter to be between 85 and 93 decibels.

Before the actual experimentation took place, the animals were conditioned to respond to the various tones of the audiometer. The desired reaction was that the shivering animal freeze and shift into a catatonic state whenever it heard any of the tones emitted by the audiometer. The tones used in training ranged from 0 to 60 decibels at 6000 cycles per second. The animal was restrained and a distinct shiver pattern usually could be detected on the polygraph after 5 minutes. A tone was then transmitted from the audiometer and immediately followed by a small electric shock of a 2 millisecond duration. (Mueller Electric Co., Model Pee Wee #45). Conditioning to the sounds was obtained during 8 to 12 sessions of twenty minutes each.

For the experimental phase, two of the guinea pigs were exposed to the continuous high speed drill sounds at different time exposures. They were restrained in the audiometric apparatus immediately after each exposure. When a distinct shiver pattern was apparent, the various tones of the audiometer were given, starting at 0 decibels and ascending upward, until the animal assumed a catatonic state and stopped the shiver pattern at one of the given frequencies. Thus the level of the temporary threshold shift could be determined. Two animals were exposed to the intermittent drill sound tape. The two control animals underwent the same procedure,

but without exposure to the drill sounds.

When the exposure time to the high speed drill sound tapes reached 24 hours for both the continuous and intermittent animals, a period of 4 weeks was allowed to elapse to ensure that the hearing damage to the animals would be complete.

To remove the organ of Corti for light microscopy observation, each animal was deeply anesthetized with ether and then quickly decapitated. The temporal bones were rapidly removed and immersed in 10% formalin solution buffered with anhydrous calcium chloride. With a small syringe, solution was forced gently in and out through the round and oval windows so as to ensure a good circulation of the solution through the inner ear. After a week of soaking in the formalin solution, the specimens were washed in distilled water and then immersed in a decalcifying solution (formic acid-sodium citrate solution) until they were soft and pliable enough for cutting. Using a surgical scissors, the bone surrounding the middle ear cavity was removed and the entire ossicular chain with the stapes and its footplate was lifted out. The posterior auditory bulla wall was opened, following which the cochlea easily could be observed. All remaining bone was severed from the cochlea. After further washing with distilled water, the tissues were partially dehydrated in ascending concentrations of alcohol, first 35%, then 50%, and finally 70%. The specimens were then embedded in parafin and cut into ribbon sections. Hematoxylin and eosin staining was used.

Under the light microscope, the organ of Corti was thoroughly examined for any evidence of cellular damage or histological change.

RESULTS

The equipment used was properly calibrated and adjusted to remain constant throughout the experimentation. Measuring and recording the sound levels of the high speed drill was maintained at a distance of 12 inches away and set to the A-weighted scale of 87 decibels. When the tapes of the drill were played back, the volume dial on the recorder was adjusted and permanently set to the 87 decibel level as registered by the decibel meter.

Measurements of the ambient background noise in the silent laboratory room was always 29 decibels during periodic checks. When the investigator spoke or moved around, the decibel meter indicated noise levels of between 40 to 52 decibels.

Every guinea pig responded differently to the learning and conditioning of the shiver-audiometric process. The animals produced evidence of reacting to the various tones of the audiometer between 8 to 12 conditioning sessions. It took one animal 5 to 15 minutes to develop a shiver pattern. A distinct and unaltering pattern of shivering as picked up by the pneumatic pulse transducer and physiograph is seen in figure 2. The paper speed was one-half centimeter per second and the pen amplitude was set to record at a maximum height of 2 inches. Any disturbance or stress the animal encountered could be detected easily as an interruption of the shiver pattern as seen in figure 3.

After the animals were conditioned to assume a catatonic state with

various tones, two of them were exposed to the continuous drill sound tape recording at the various exposure times listed in table III. Two animals were subjected to the intermittent sound tape recording for the various time periods listed in table IV.

Table V discloses the resulting minimum threshold shifts the animals exhibited after each exposure to the continuous drill noise. The values represent the first indication at which the animals heard the tone and assumed a catatonic state. The polygraph registered this quite clearly as seen in figure 4.

Table VI presents the temporary threshold shift values obtained after the guinea pigs were exposed to the intermittent drill noise sounds. As shown in table VI and figure 5 both guinea pigs responded immediately to the lowest decibel level tones emitted from the audiometer.

After being properly conditioned to react to the audiometric tones, the control animals continued to exhibit no temporary threshold shifts whatsoever upon testing.

Before each time the animal was to undergo an exposure to the drill noise, a threshold test was taken to determine if the animal had fully recovered from the previous exposures. Every test of this type showed the animals responded to the lowest decibel tone, 5 decibels. Threshold tests were also taken immediately before decapitation.

On the average, decapitation and cochlear extraction took 20 minutes. After the cochleas were chemically treated, embedded in parafin, serially sectioned and stained, no observable lesions could be seen in any of the

Table III

Continuous Drill Noise

Time Exposures

(in minutes)

12
45
150
180
210
240
300
360
450
720
960
1200
1440

Table IV

Intermittent Drill Noise

Time Exposures

Actual drill sounds (in minutes)	Actual time tape played (in hours)
<hr/>	<hr/>
12	1:10
45	4:30
150	15
180	18
210	21
240	24

* Tape played 1 minute on, 4 minutes off.

Table V

Temporary threshold shifts of exposure times with the continuous drill sounds.

Exposure time (in minutes)	Temporary threshold shifts in decibels	
	guinea pig one	guinea pig two
12	no TTS	no TTS
45	no TTS	no TTS
150	no TTS	no TTS
180	15	5
210	15	10
240	25	25
300	35	30
360	35	30
450	35	35
720	35	35
960*		
1200	40	40
1440	45	40

* Results unreliable due to physiograph equipment failure.

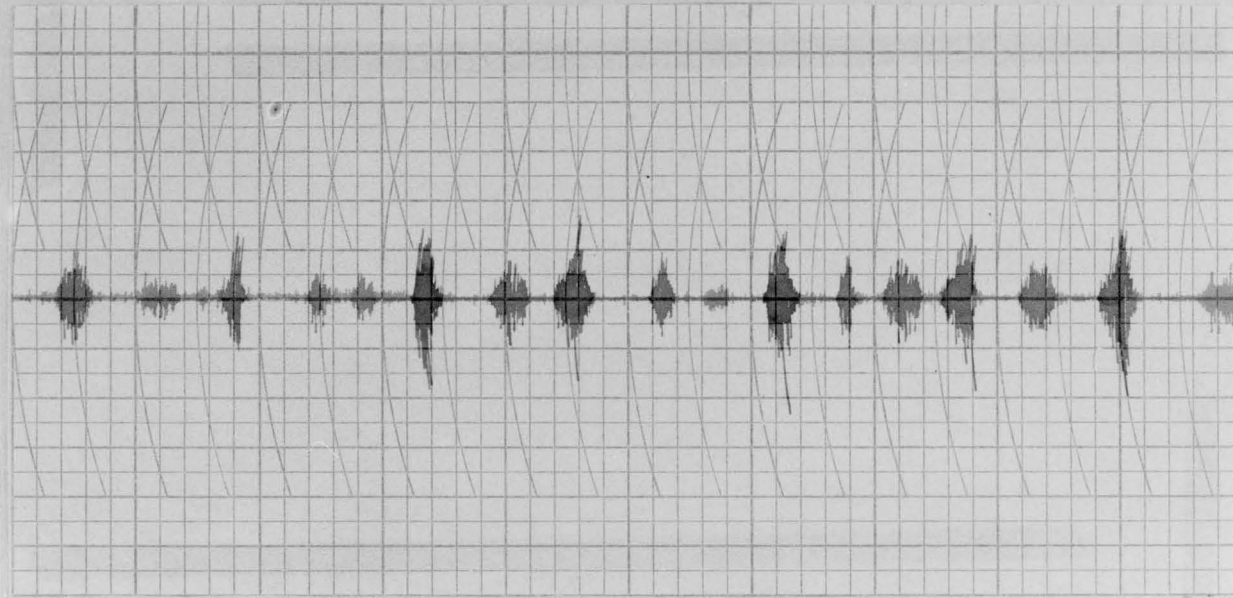
Table VI

Temporary threshold shifts of exposure times
with the intermittent drill sounds.

Exposure time of drill sounds (in minutes)	Temporary threshold shifts (in decibels)	
	G.P. three	G.P. four
12	no TTS	no TTS
45	no TTS	no TTS
150	no TTS	no TTS
180	no TTS	no TTS
210	no TTS	no TTS
240	no TTS	no TTS

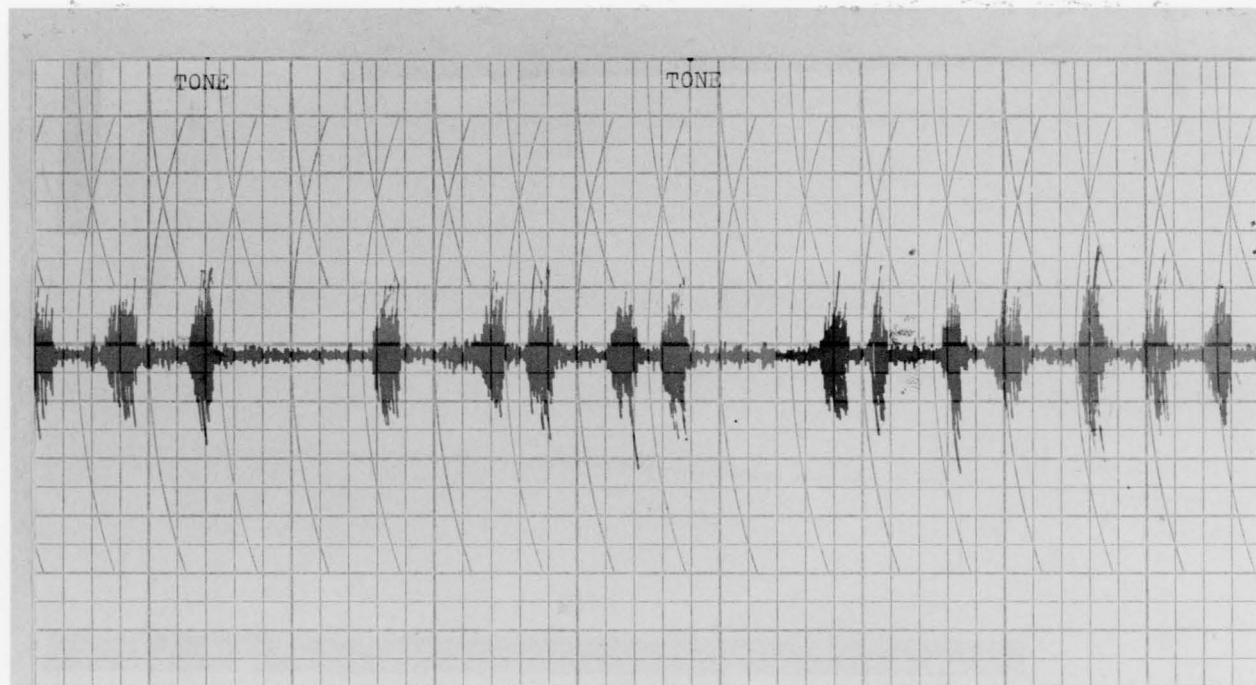
sections. None of the nerve fibers or blood vessels appeared to be reduced in number. The supporting structures surrounding the organ of Corti seemed normal. No loss of the mesothelial cells which underlie the basilar membrane or damage to the internal or external hair cells was in evidence. No ruptures of the organ of Corti from the basilar membrane in any of the sections was observed. (c.f. figures 6,7,8).

Figure 2



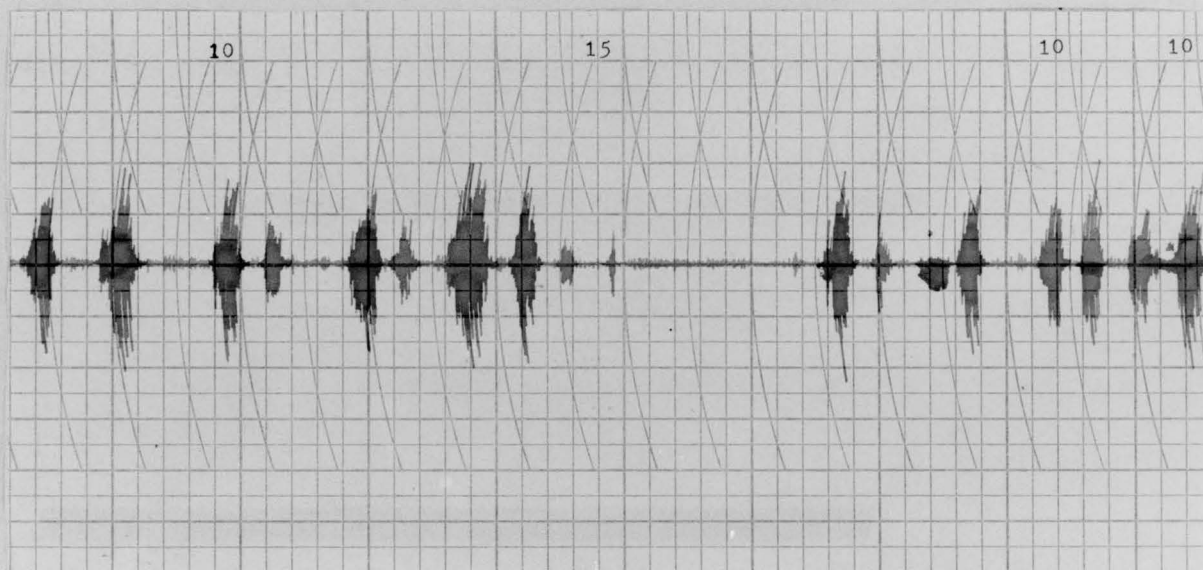
Regular shiver pattern recorded on the physiograph

Figure 2. Regular shiver pattern recorded on the physiograph.



Regular shiver pattern with a tone sounded where
the animal assumed a catatonic state.

Figure 3. Regular shiver pattern with a tone sounded
where the animal assumed a catatonic state.



First tone guinea pig number one was able to distinguish was at 15 decibels when exposed to 180 minutes of continuous drill noise as recored by the physiograph.

Figure 4. First tone guinea pig number one was able to distinguish was at 15 decibels when exposed to 180 minutes of continuous drill noise as recorded by the physiograph.

Figure 5



No threshold shifts indicated with exposures to the intermittent drill sounds.
The animal responded to every tone. Guinea pig number three--- 240 minutes of
drill exposure.

Figure 5. No threshold shifts indicated with exposures to the intermittent drill sounds. The animal responded to every tone. Guinea pig number three - 240 minutes of drill exposure.

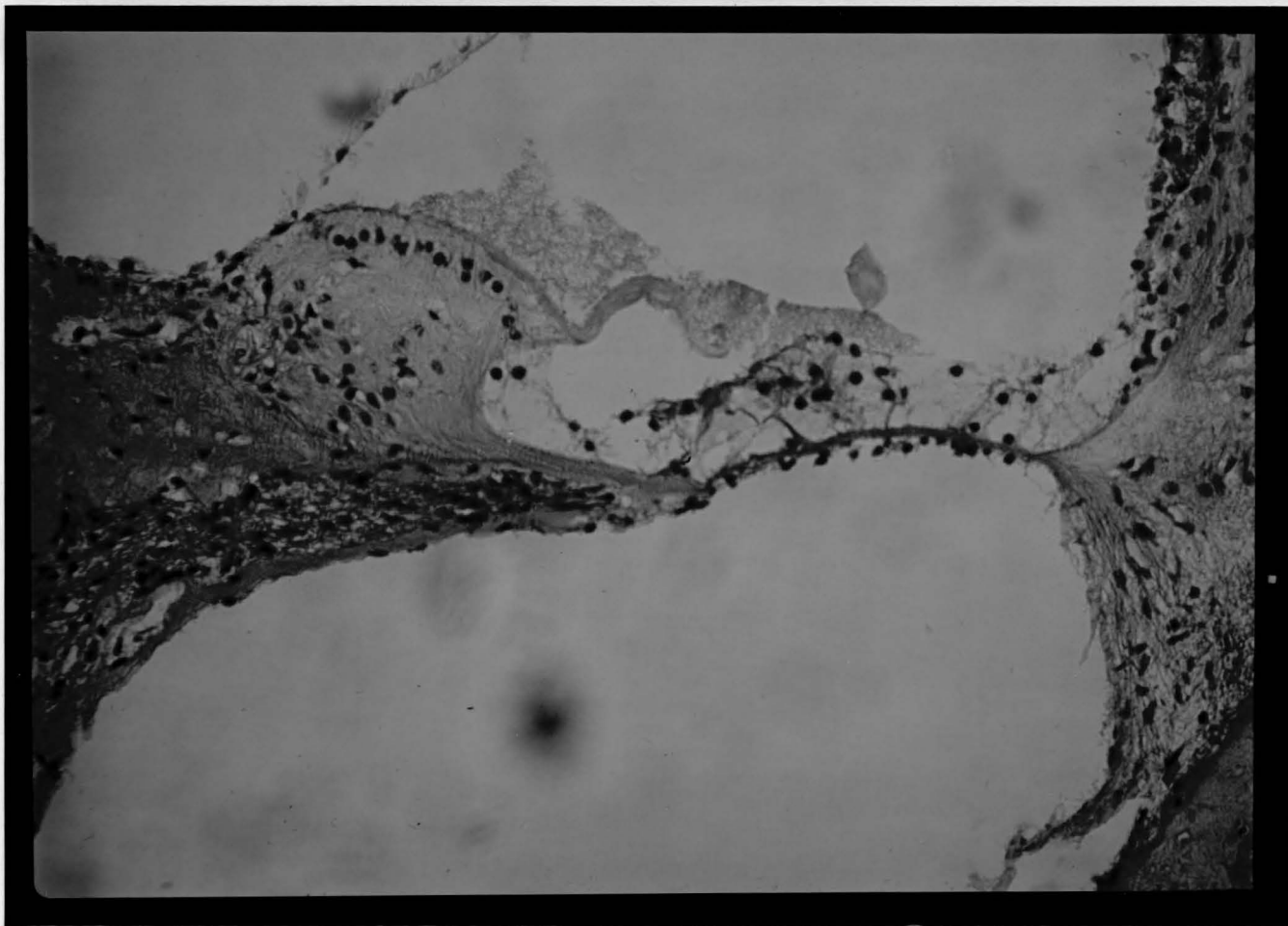


Figure 6. Organ of Corti X45 of guinea pig one exposed to the continuous drill sounds.

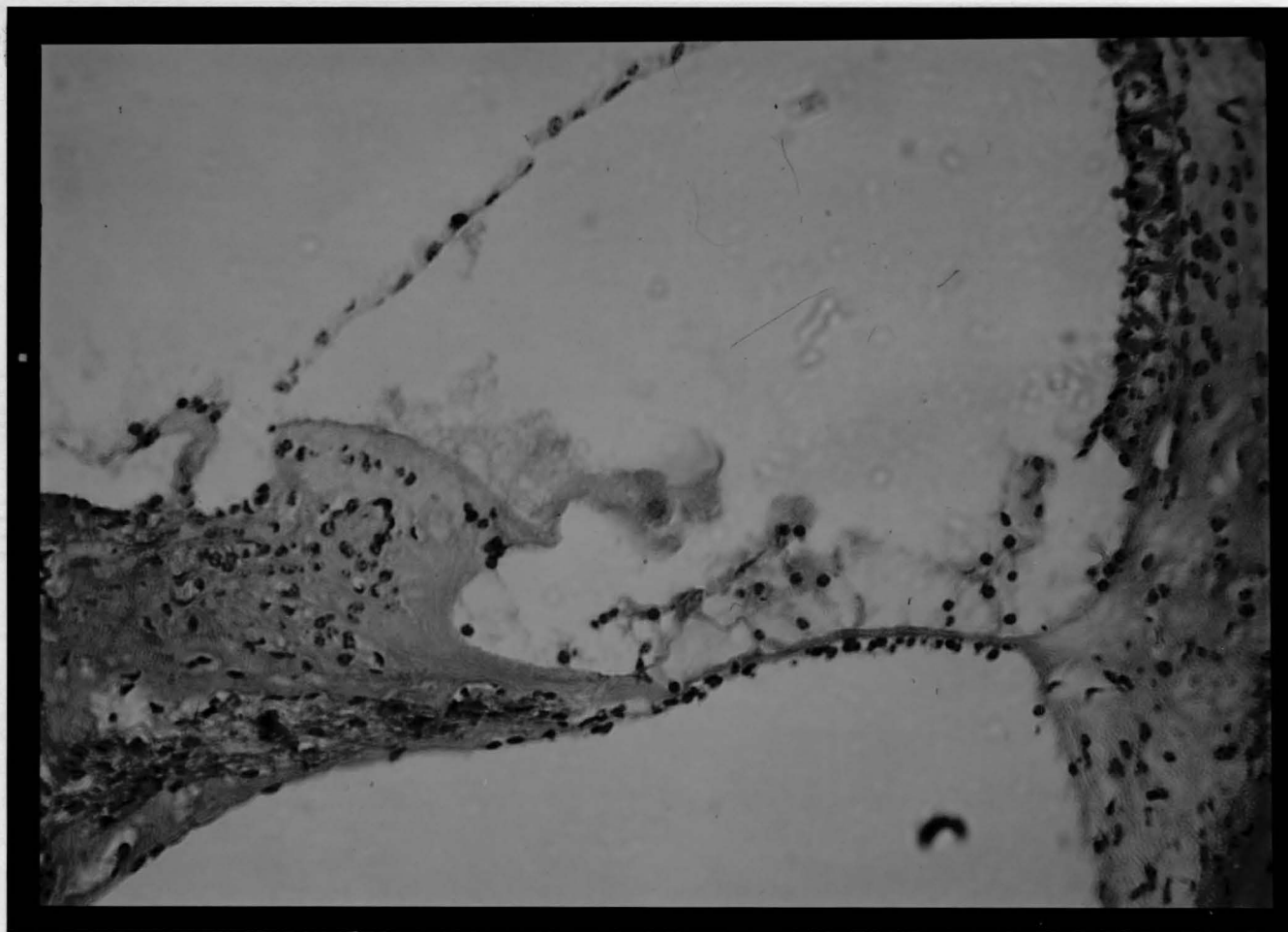


Figure 7. Organ of Corti X45 of guinea pig four exposed to the intermittent drill sounds.

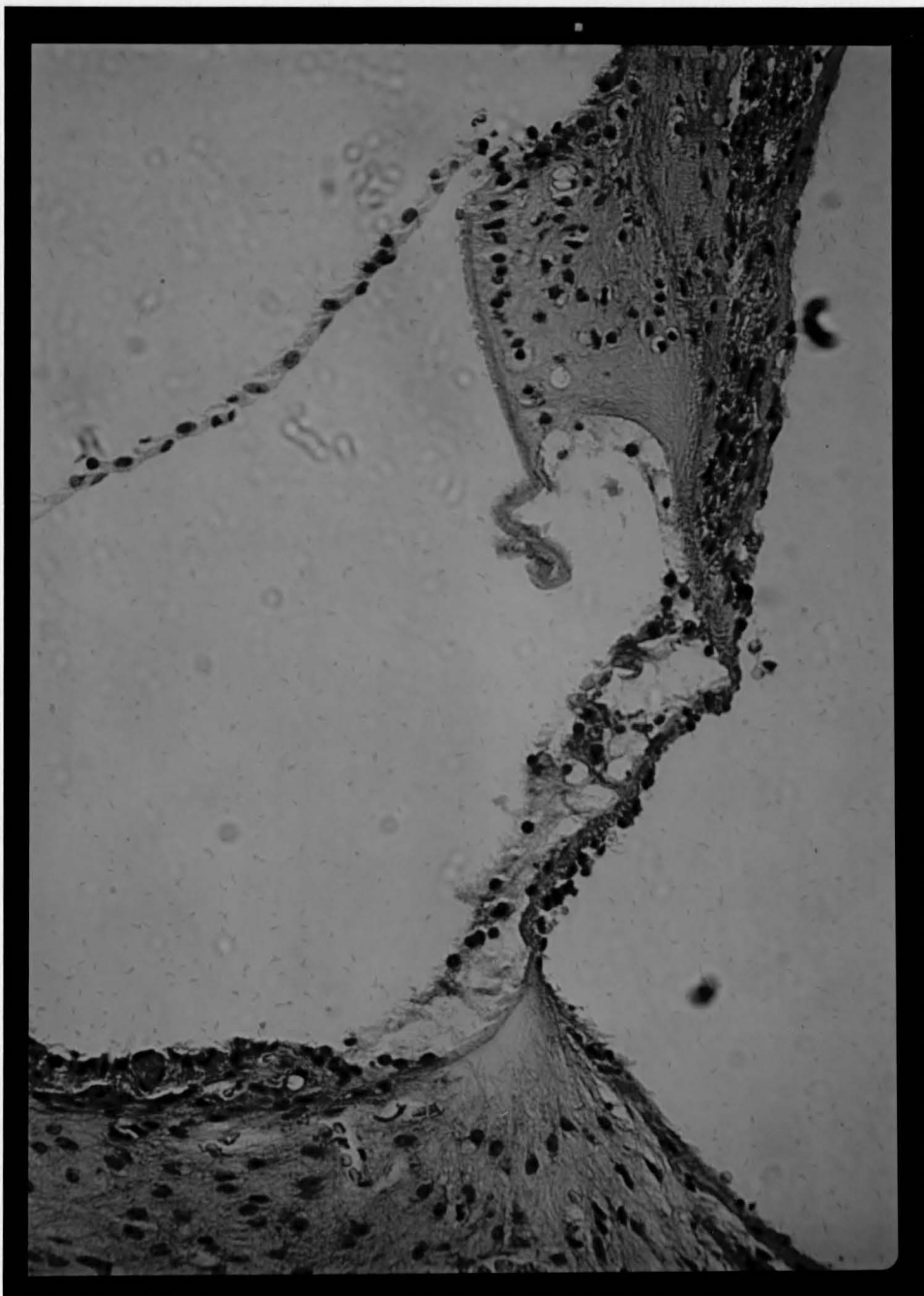


Figure 8. Organ of Corti X45 of a guinea pig used as a control animal.

DISCUSSION

For the past twenty years, dental researchers have been attempting to answer questions raised as to whether or not high speed drills present a hazard to the dental community's hearing. The factors considered are intensity, length of exposure, intervals between exposures, frequency of vibration and susceptibility. Many different investigations and opinions have been reported concerning these factors. Some studies generate evidence of a significant hearing loss (Taylor, 1962: Weatherton, 1972), while others conclude the use of the high speed drill is not detrimental to hearing (Hopp, 1962: Ward, 1969: Skurr, 1970: Forman-Franco, 1978).

With these five factors in mind, it was the purpose of this experiment to investigate the exact effects high speed drill sounds have on the hearing mechanism. Calibrations and investigations were made to measure if temporary threshold shifts and/or permanent threshold shifts were present after various time exposures to drill sounds. The parameters of continuous noise and intermittent noise were considered. Histologic studies were undertaken directly on the guinea pig cochlea since such studies were experimentally non-existent on human subjects. It was hoped that a standard would be established as to what time periods of exposure to high speed drill sounds would be needed to produce a threshold shift and if those exposures would eventually lead to permanent injury.

Since no dentist is exposed to significant continuous high speed

drill sounds throughout his working day, continuous drill sound measurements were taken nonetheless to establish a standard and set limits to what the effects could be. With exposure times up to 150 minutes, no temporary threshold shifts were detected. With the dentist presumably never exceeding this level of continuous drill sound, one would assume a measureable temporary threshold shift would not happen. Temporary threshold shifts were detected at 180 minutes and above with the continuous noise. All the animals recovered to pre-threshold levels after each test with no permanent effects detected. Delays of 5 to 15 minutes were encountered between the cessation of sound to the time of audiometric testing to allow the animals to become cold and shiver in a regular pattern. The animals may have had a temporary threshold shift at the lower levels but by the time they were accurately tested, some recovery may have occurred.

Throughout his working day, a dentist's exposure to the high speed sounds occurs intermittently. The various time exposures established in the literature were used in this study. It was found that no temporary threshold shifts were observed 5 to 15 minutes after the cessation of sound with intermittent sound exposures from 12 to 240 minutes. Apparently, the hearing mechanism has the capability to recover between noise exposures from any damaging effects of high speed sounds. With the magnitude of the shift in threshold sensitivity being a function of the intensity and duration of the noise, one would expect the high speed sounds a dentist experiences in his average day will cause no measureable damage to his hearing.

What makes temporary threshold shifts particularly hazardous to hearing is the fear they may evolve into a permanent threshold shift. Chronic acoustic trauma could damage critical tissue barriers such as the reticular lamina or cause degeneration of the organ of Corti. Upon histologic examination, no structural damage or unusual deviations in the cochlea were seen in our specimens. The duration and intensity of the high speed sounds the subjects were exposed to apparently were not at levels harmful enough to cause even minor abnormalities or variations. No loss of mesothelial cells which underlie the basilar membrane was detected. This loss is generally accepted as the first indication that damage has occurred.

Shiver-audiometry proved to be an excellent method to measure the lowest decibel level detected by the guinea pig. The animals were easy and quick to adapt to training. The shiver characteristic, being an innate and constant factor for the guinea pig, did not have to be taught to the animal. The polygraph instantly registered when the animal perceived the audio tones and allowed a direct measurement of any temporary threshold shifts. In the past fifteen years, its methodology has been increasingly used. Even though guinea pig hearing is more acute than human hearing, its measurements and translations have proved invaluable to the better understanding of the human hearing mechanism.

Most high speed drills produce an intensity fluctuating between 70 to 95 decibels. High speed drill studies have shown that the intensity runs in or borders on the danger zone when set with the damage-risk criteria curve. The damage-risk criterion for continuous 8 hour exposure

is 90 decibels. Individual dentists in all the dental specialties and types of practices have had their exposure times measured and averaged. In a period of 8 hours, variations of total exposure time ranged between just 12 to 45 minutes. Thus, even though the intensity of the drills approaches a dangerous level, the length of exposure the dentist is submitted to in an average day should bring the levels to within tolerable limits regarding damage to hearing. Some new drills do emit intensity levels above 95 decibels as cited in the literature and may extend into the danger zone and not within proper tolerable limits.

It is commonly accepted that above a frequency of 3000 cycles per second, the ear is susceptible to damage especially in the first turn of the cochlea. Studies have shown that most of the energy from the high speed drill centers in frequency levels from 4000 to 8000 cycles per second. Investigators have found some dentists with slight losses of hearing at the 4000 to 6000 cycles per second range, but no statistically significant results. Normal everyday speech discrimination and word intelligibility are found between the 1000 to 2500 cycles per second range. It can be expected that slight losses in the high frequency range around the 6000 level will not present difficulties in speech discrimination for the dental population.

The susceptibility of the individual to hearing loss is an important factor to be considered and is in evidence in many studies where variance of results can be seen with subjects whether they be human or animal. Loss of hearing resulting from aging is a general phenomenon at the 8000 cycles per second range, decreasing with a regular pattern as the aging

process progresses. When comparing the hearing levels, as adjusted for age, of dentists with the general population, no statistical differences can be detected. This suggests that as a practitioner experiences a gradual hearing loss, it probably is an effect of aging.

This study was set up to simulate the high speed drill sounds a dentist is exposed to in a very small period of time. Long term studies are needed with both animals and dental practitioners to find out if small increments of high speed drill exposure accumulated year after year can cause damage in the long run.

CONCLUSIONS

A study concerning the effects of high speed drill sounds must take five factors into consideration. They are the intensity of the stimulus, the frequency of vibration, the exposure duration, the intervals between exposures, and the susceptibility of the individual.

This study investigated the direct effects on the guinea pig various exposures to drill sounds had on hearing and if any histological damage was evident. The shiver-audiometric method developed by Anderson and Wedenberg in 1965 was employed to effectively measure temporary threshold shifts and permanent threshold shifts that could occur after exposure to the high speed drill sounds.

It was found that high speed drill sound given continuously for 12, 45, and 150 minutes produced no detectable temporary threshold shifts. The guinea pigs did exhibit temporary threshold shifts with continuous noise exposure from 180 to 1440 minutes.

When other guinea pigs were exposed to drill sounds intermittently (1 minute of drill sounds, 4 minutes of silence) from 12 to 240 minutes, no temporary threshold shifts were detected. The control guinea pigs gave no hearing threshold deviations. In all the guinea pigs, no permanent threshold shifts were detected.

Cochlear extraction and histologic examination from all the guinea pigs exhibited no observable lesions or deviations. Loss of mesothelial

cells which underlie the basiliar membrane or hair cell damage was not detected.

A dentist's exposure to high speed drill noise occurs intermittently in his practice. The exposure time of a dental practitioner has been measured to average between 12 and 45 minutes. Even though the intensity and frequency levels of a high speed drill approach the danger zone when set in the damage-risk criterion curve, the dentist's limited exposure time and intervening intervals of rest indicate no temporary threshold shifts or inner ear damage is likely to occur. This study concurs with these findings. However, chronic exposure year after year to these short intermittent sounds needs to be investigated for any long term damage. The aging process and each individual's susceptibility are now thought to play a major role in the hearing loss of dental practitioners.

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The thesis is therefore accepted in partial fulfillment of the requirements for the degree of Master of Science in Oral Biology.

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