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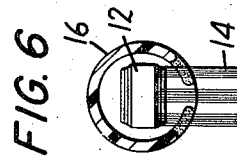
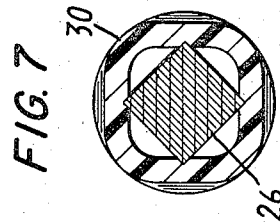
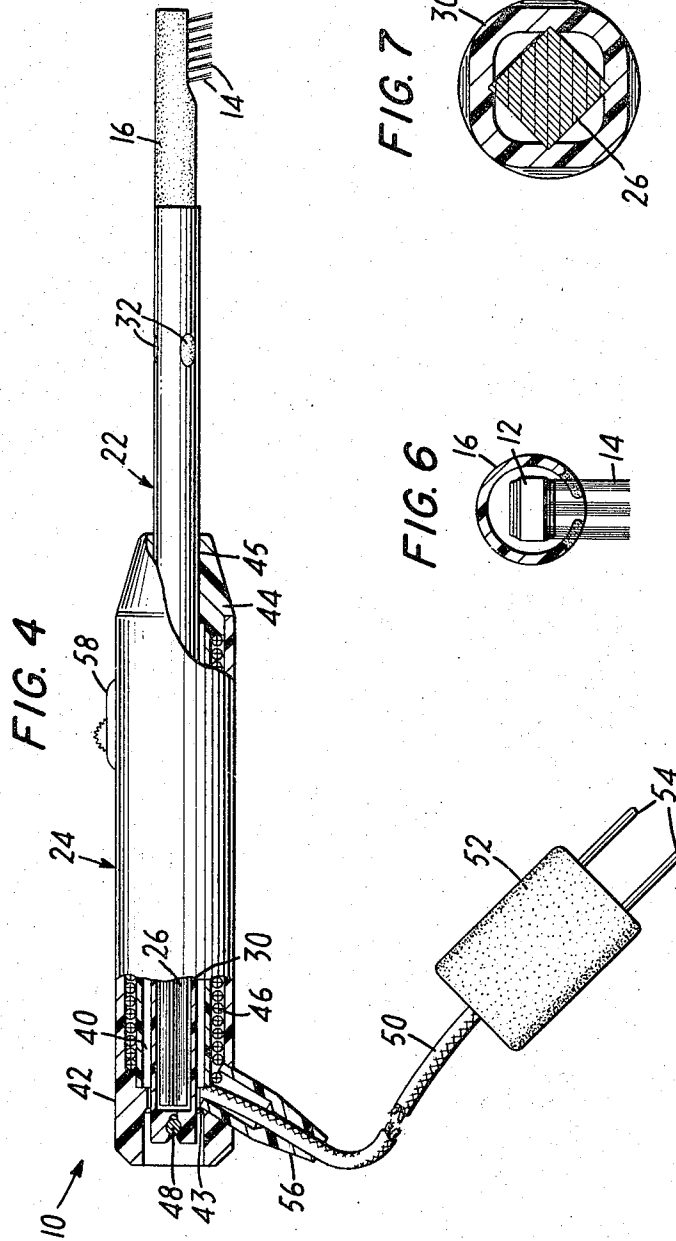
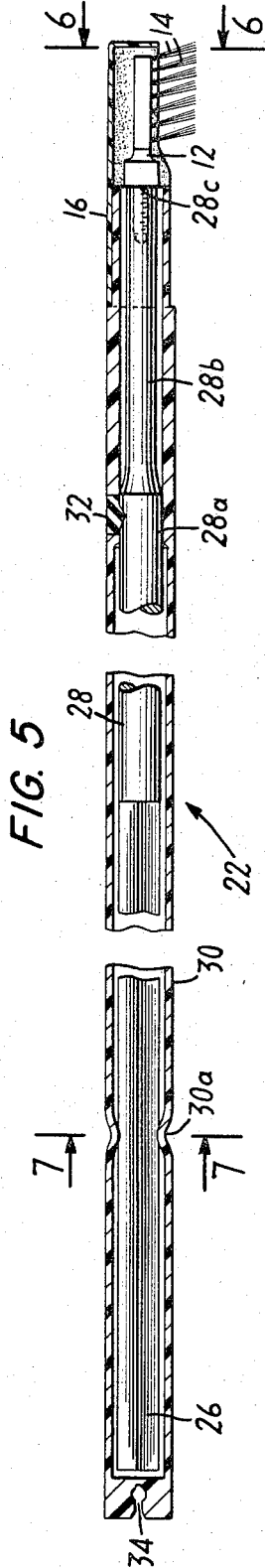
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METHOD AND APPARATUS FOR ULTRASONIC CLEANING OF TEETH

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2 Sheets-Sheet 2



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METHOD AND APPARATUS FOR ULTRASONIC CLEANING OF TEETH

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This invention relates to methods and apparatus for oral hygienic care, and more particularly to methods and apparatus for personal dental care employing ultrasonic energy suitable for regular use in the home.

Within the past several decades, the importance of oral health to the individual's overall physical well being has been recognized and much progress in professional and personal dental care has been made. Along with periodic examination and treatment by professionally trained dentists, it has been established that significant benefits are derived from regular dental care performed in the home by the individual himself. It is universally recognized, for example, that regular brushing of the teeth, particularly after every meal, serves to dislodge food particles which ordinarily are retained adjacent the teeth and which, if allowed to remain, would cause decay and dental caries. When properly administered, regular brushing also serves to maintain good circulation in gingival tissue, thereby lessening the likelihood of gingival disease, one of the prime causes of premature loss of teeth. Perhaps of less, but nevertheless significant, importance are the stain removal and brightening actions resulting from regular brushing, which contribute noticeably to the appearance of the individual.

Until recent years, personal dental care was effected solely through manual brushing, generally with some form of dentifrice. The effectiveness of this technique depends in large measure upon the assiduousness of the individual in performing the necessary manual motions for the required period of time. A proper brushing, which should be performed twice a day or more, requires a certain amount of manual dexterity, as well as patience. The effort is particularly unappealing to children and it is only with great perseverance that parents are able to train their offspring in proper dental care. Furthermore, with a conventional toothbrush it is extremely difficult, if not impossible to reach into the narrow spaces between the teeth and thus maintain the interproximal areas free of debris, or to remove foreign particles trapped at the gingival crest, i.e., the gum line.

In recent years, manually actuated brushes have been replaced in increasing proportion by motor driven toothbrush devices. These implements take many forms, but all consist basically of an electric motor powered by battery or from a standard 60 cycle source, and a brush element which is driven by the motor. The motion imparted to the brush element may be rotary, longitudinal, or oscillatory, either in a longitudinal or transverse mode, or combinations thereof. In all of the devices of this type known to the present inventors, the movement of the brush head itself is effected at a rate of speed related to commercial power frequencies, i.e., 60 c.p.s., and the brush element may move on the order of from 60 to 120 times a second.

Such motor driven toothbrushes provide advantages over conventional manual brushing. Since a great many more brushing strokes per second are provided by the powered device, substantially more brushing is performed by the user in a given amount of time. This has the effect of condensing the time necessary for an adequate brushing to a small fraction of that required when done by hand. Also, since the motor provides the power necessary to move the brush head in the prescribed manner, it

is only necessary for the user to guide the brush over the tooth surfaces to achieve proper results. These devices then are appealing in that they are relatively simple to use and also serve to provide what amounts to an increased amount of brushing per unit time, as compared to conventional manual brushing.

However, the use of these conventional motor driven toothbrushes does not overcome many of the disadvantages of manual brushing. Although a somewhat increased scrubbing action relative to manual brushing occurs at those tooth surfaces readily contacted by the bristle ends, stains and foreign deposits in the interproximal and gingival crest, or gumline, areas are reached no better by the motor driven toothbrush than by the manually actuated brush. Accordingly, the agents responsible for many dental caries and gingival disease are not removed by substitution of a conventional motor driven toothbrush for the manually actuated implement.

Previous work by the present inventors in the application of ultrasonic energy to dentistry, has established that ultrasonic energy can be useful in the care and treatment of teeth. In Patent No. 3,076,904, granted Feb. 5, 1963 for "Acoustically Vibrated Material Cutting and Removing Devices," assigned to the present assignee, there is disclosed an ultrasonically actuated device, which, inter alia, has found important applications in the dental office. The apparatus of the patent utilizes a hardened steel tip vibrated at an ultrasonic rate for drilling teeth in the treatment of dental caries, and also under proper control of the dentist, for the removal of deposits of tartar and scale from tooth surfaces. In the use of this tool for the removal of deposits of tartar and scale, it is found that in the wet field supplied by a warm water spray impinging on the tool tip, a relatively gentle pecking at the deposits results in their rapid and efficient removal. Thus the time consuming, imperfect, and sometimes painful manual scraping usually performed by the dentist in the cleaning of teeth can be avoided.

However, while the benefits of ultrasonic energy have been successfully demonstrated and are now in wide use in dental offices, no techniques or apparatus employing ultrasonic energy for personal home dental care has heretofore been devised. As will be appreciated, the dental instrument described in the aforementioned patent must be carefully manipulated by a skilled dentist or dental technician to avoid injury to the teeth or gingival tissue. It will be recognized of course, that professional dental treatment is not administered except at relatively long intervals and the cleaning techniques employed by dentists must be considerably more powerful than those utilized in daily oral hygienic care performed by the individual at home.

It is the primary object of the present invention to provide methods and apparatus employing ultrasonic energy for personal oral hygienic care which enables significantly better cleaning of teeth and which is completely safe for use by untrained adults or children in the home on a regular basis.

It is a further object of this invention to provide novel and improved cleaning techniques and apparatus for regular personal oral hygienic care giving excellent cleaning results in the hard to reach interproximal and gum line areas and in general, in areas around the teeth that are normally relatively inaccessible.

Still another object of the present invention is to provide a novel form of apparatus employing ultrasonic energy for use in regular personal oral hygienic care in which the cleaning element or brush itself is readily replaceable, thereby enabling a single power handle to be used with a plurality of cleaning elements.

Yet another object of the present invention is to provide an improved apparatus for regular personal oral hygienic care, employing ultrasonic energy, in which the cleaning

element itself may be used apart from the remainder of the apparatus as a manually actuated toothbrush.

The present inventors have discovered that, when applied under proper control to tooth and gingival surfaces in the human mouth, ultrasonic energy may be successfully employed for regular oral hygienic care without any damage to tooth surfaces or gingival tissues. These ultrasonic cleaning techniques provide a significantly increased cleaning ability, particularly in the interproximal and gum line areas where presently known brushing techniques are inadequate. Briefly, in accordance with the invention, a cleaning member, which preferably includes a plurality of individual cleaning elements, such as the bristles on a brush, are vibrated at an ultrasonic rate and manually moved over tooth and gingival surfaces under relatively light pressure. Although not necessarily limited thereto, the combined ultrasonic and manual movement of the cleaning member may be performed in the presence of a fluid, such as water added specifically for the purpose, or the natural fluids present in the human mouth and in the presence of the usual dentifrices such as toothpaste and tooth powder. The unique properties displayed at the tips of an ultrasonically vibrating member such as a brush, enable greatly improved cleaning results to be achieved, particularly in areas where manual or conventional motor driven toothbrushes cannot reach. The ultrasonic energy is applied to the tooth and gingival surfaces such that no damage whatsoever to the surfaces will result. On the other hand, because of the greatly improved cleaning power, the build-up of tartar and scale deposits in the interproximal and subgingival areas is significantly lessened, promoting a much higher degree of dental health than is possible with ordinary methods of dental hygienic care.

The apparatus in accordance with the invention is comparable in size and configuration to conventional motor driven toothbrush implements and is eminently suitable for home use by adults and children alike without special knowledge or training. The unit is constructed basically of three elements. The first, the cleaning member or brush head, may take several different forms but in general is similar to conventional toothbrush heads, having a base member onto which are affixed a plurality of bristles or bristle-like elements. The brush head is rigidly affixed, such as by screw threads, to one end of a narrow, elongated vibrating element, such as of magnetostrictive piezoelectric or ferrite material, which can be oscillated. In the illustrated embodiment, the elongated member is completely enclosed in a nonmagnetic, fluid-impervious material, e.g. plastic, aluminum, etc. and forms with the brush head a brush insert which approximate the size and shape of an ordinary manual toothbrush. In fact, the individual brush insert may be used in that fashion if for some reason the ultrasonic generator apparatus is not available at the moment. It will be understood however, that this is but an added benefit of the particular structure shown and may be dispensed with if deemed unnecessary.

The third element of the apparatus is the driving handle which is of a size and shape to be held conveniently in the hand. The handle member includes an axial bore for receiving in close fitting engagement the end of the brush insert opposite the brush head. A catch is provided in the bore for holding the brush insert with sufficient force to prevent removal during use, but to allow ready removal by hand. Alternating electrical signals are supplied to suitable elements within the handle member to drive the vibrating element. With the brush insert positioned in the handle member and alternating electrical signals at an ultrasonic frequency supplied thereto from an oscillator of convenient form, longitudinal vibrations are induced in the transducer portion of the insert, which in turn vibrates the brush head. As a result of the unique mounting arrangement, none of the vibratory energy or heat from the transducer element is transmitted to the hand of the user.

In family use for example, a single handle member and oscillation generator would be supplied, together with a number of brush inserts, one for each member of the family. Each user simply inserts his own personal brush insert into the handle prior to cleaning his teeth. In addition, the brush heads themselves on the brush inserts may be replaced periodically as they wear, without the necessity of replacing the entire transducer element.

The foregoing and other objects, features and advantages of the invention will become more apparent from the following detailed description thereof, when read in conjunction with the accompanying drawings in which:

FIGS. 1A, 1B, 2 and 3 illustrate the cleaning apparatus of the present invention in relation to a set of human teeth, and are helpful in explaining the operation of the present invention;

FIG. 4 is an assembled view, in partial cross section, of the cleaning implement according to the present invention;

FIG. 5 is a sectional view of the brush insert alone illustrating the various components thereof;

FIG. 6 is a section through the brush insert of FIG. 5 taken along the lines 6—6; and

FIG. 7 is a sectional view through the magnetostrictive portion of the brush insert of FIG. 5, taken along the lines 7—7.

Turning now to FIG. 1A, there is illustrated a portion of a dental cleaning implement in accordance with the invention in operative position against the teeth. The cleaning implement 10 will be described in detail hereinafter and for present purposes it is sufficient to indicate that it includes a cleaning member or brush head 12 in which are mounted a plurality of cleaning elements or bristles 14. Each of the latter may be composed of a plurality of individual bristle filaments 14a. It will be seen that the bristles 14 are not perpendicular to the member 12 but slope slightly forwardly with respect thereto. This is not necessary but, as will become apparent hereinafter, is the more desirable orientation. A housing 16 of plastic, or other water resistant material may surround the brush head as shown, leaving the bristles 14 exposed.

The brush construction thus far described resembles closely an ordinary manually actuated toothbrush. In accordance with the invention, the brush portion of the implement 10 is positioned against the teeth 100 in the usual manner during the brushing operation. That is, the brush member is inserted in the mouth and positioned adjacent the tooth surfaces with a relatively light pressure such that at any given time, several of the bristles 14 are in contact with tooth surfaces, while others are displaced therefrom by varying amounts. As the implement 10 is moved manually to pass the brush portion across all of the tooth surfaces, the bristles 14 randomly assume positions in contact with and displaced from tooth surfaces. As in the case of manual brushing, the bristle elements 14a rarely assume positions such that they extend deeply into the interproximal areas 100a. However, they are moved across the spaces between adjacent teeth as the implement is moved by the user across the tooth surfaces.

While the cleaning implement 10 is being manually moved over the tooth surfaces, much in the manner in which conventional brushing is performed, the brush head 12 is vibrated at an ultrasonic rate in its longitudinal direction, as indicated by the two headed arrow in the figure. Since the bristles 14 are carried in the brush member 12, they too vibrate at the ultrasonic frequency. Accordingly, as the bristles 14 pass over the tooth surfaces and across the interproximal areas, the ends thereof are vibrating at an ultrasonic rate to provide improved cleaning results. It has been found that with the application of ultrasonic vibrations to the cleaning member 14 at a frequency in the order of from 15,000 to 40,000 c.p.s., there are obtained at the tooth and gingival surfaces improved cleaning results not obtainable with manual or conventional motor driven toothbrushes.

In considering the action of conventional mechanically driven toothbrushes, it was concluded that its improved cleaning ability as compared to a manual brush was due simply to an increased scrubbing action. For example, a mechanically driven brush having a bristle stroke of .125" and operating at a frequency of 120 c.p.s. (both typical values) will have a peak velocity of about 4 feet per second at the bristle tips and a bristle tip will cover a distance of approximately 15 inches in one second. Both values are substantially greater than can be achieved by hand brushing.

A typical ultrasonically driven toothbrush in accordance with the present invention would have a bristle stroke of about .001" (actually somewhat less) and would operate at a frequency of 20,000 c.p.s. This calculates out to a peak velocity at the bristle tips of approximately 5 feet per second and distance traveled by a bristle tip of about 20 inches per second.

The ultrasonically driven brush however, does differ from motor driven brushes in that both the repetition rate of the bristle motion and the accelerations at the bristle tips are many times greater in the ultrasonic brush. In the case of the example given above, the ultrasonic brush has a repetition rate 167 times greater than the motor driven brush and provides a peak acceleration at the bristle tips of some 200 times that of the motor driven brush. These latter two factors, unique to ultrasonic actuation, are believed to be primarily responsible for the greatly enhanced cleaning effectiveness exhibited by the ultrasonically driven brush of the present invention.

The foreign deposits normally found on teeth may be generally characterized as stain, plaque, and calculus or tartar. Stain and tartar are both adherent deposits on teeth while plaque is somewhat softer and less adherent, such as soft food deposits found in the crevices on and between teeth. Observation has indicated that hand brushing has only limited ability to remove stain and little or no effect on tartar deposits. Conventional low frequency motor driven tooth brushes are somewhat more effective in removing stain but are similarly ineffective against calculus. In both cases, the ability to remove plaque from relatively inaccessible areas is limited.

Comparative tests have shown that not only does the ultrasonically driven brush remove tartar deposits, where others have been almost completely ineffective, but it also removes stain and interproximal deposits in a significantly superior fashion. The improved cleaning results are believed traceable to the high repetition rate of vibration and the peak accelerations available at the bristle tips, in accordance with the following analysis.

It is known, from observation, that the ultrasonically vibrating bristle clusters are accompanied by a vigorous cavitation action when the cleaning area is wet. This is a direct consequence of the high peak accelerations and thus introduces a factor not present in other known tooth cleaning aids. Thus, cavitation action in the interproximal areas of the teeth would tend to remove plaque in a manner analogous to the way in which a cavitating cleaning liquid removes dirt from inaccessible regions of a complex watch mechanism.

A further cleaning action believed to occur at the tooth surfaces subjected to the action of the ultrasonically vibrating bristles is akin to a material removing method well known in industry as ultrasonic impact grinding. This effect is exhibited in the presence of high frequency vibration, minute strokes of vibration, a cavitating liquid field and a low density of material-removing particles in the liquid field. To obtain material removal under these conditions, it is necessary simply to press the vibratory element or elements lightly against the work surface, e.g. a tooth. Where ordinary dentifrices are used, they supply the low density of material-removing particles in the cavitating liquid field. In the event the ultrasonic brushing is carried out in the presence of a simple liquid, the process will

take place as soon as appropriate material-removing particles are present. These may be provided, for example, by particles of already removed tartar or calculus suspended in the liquid. Tartar or calculus is a conglomerate of gritty particles which would serve admirably as an agent to remove further deposits. Moreover, these particles not being as hard as the tooth structure would not cause damage to the teeth.

The superiority of the ultrasonic tooth cleaning techniques and apparatus of the invention over other brushing procedures are believed to result from a combination of the above effects which are unique to ultrasonic phenomena. As the toothbrush is moved over the tooth surfaces, the several effects will be exhibited in varying degrees. However, when used daily over a period of time, it can be expected that substantially all of the tooth surfaces will experience the overall improved cleaning action to an extent that previously deposited stains, calculus and plaque will be removed and the user's mouth and teeth thereafter will be maintained in a uniquely clean state.

FIG. 1B, which is an enlargement of the encircled portion of FIG. 1A, is helpful in explaining how the foregoing phenomena are believed to be concomitantly utilized in accordance with the invention to provide the improved cleaning results obtained. With the brush member 12 vibrating longitudinally in the direction indicated by the two-headed arrow, the tips of individual bristle filaments 14a, which may be inclined forwardly with respect to the brush head 12, vibrate with orthogonally related components of motion, as indicated by the crossed arrows in the figure.

In utilizing the brushing implement, the brush head is inserted in the mouth in the usual manner and moved across tooth and gingival surfaces with the bristle clusters 14 in relatively light contact with the tooth surfaces. As the brushing implement is manually moved throughout the mouth, the bristle clusters 14 will randomly assume different positions with respect to the tooth and gingival surfaces. For example, at any one time it is likely that some of the clusters will be in direct contact with tooth surfaces while others will be spaced therefrom by varying amounts depending upon the angles of the tooth surfaces and the direction of orientation of the brush member. Thus as shown in FIG. 1B, one bristle cluster may be in contact with a tooth, the subsequent bristle cluster may be slightly spaced from an adjacent tooth and finally a further bristle cluster may be somewhat more distantly spaced from the next tooth.

As discussed above, it is evident that different bristle clusters, depending upon their relation to any particular tooth and its immediate environment, will be able to exert a variety of tooth and gum cleaning and conditioning influences. Cavitation effects will be engendered by the various clusters, in differing degrees depending on the spatial distribution of the clusters and cavitating liquid relative to the various aspects of the tooth and gum surface concerned, for example, into the regions such as designated 100a. The effects inherent in the combined action of ultrasonically vibrating bristle elements and associated fluid make the present invention unique in the dental field, and result in a greatly improved cleaning action as compared to the simple scrubbing provided by mechanical or manually moved brushes.

As the brushing implement is manually moved through the mouth, in much the same way as in manual brushing, the bristle clusters will assume different positions with respect to different tooth surfaces. During a period of several minutes of brushing, on the average all of the tooth surfaces will be exposed to at least one, and probably all, of the above-described cleaning actions. Projected over a period of regular use, such as twice or three times daily, it will be realized that each of the tooth surfaces, including interproximal areas and gum line surfaces will be subjected to much more intensive cleaning than is available with other known cleaning implements.

FIG. 2 illustrates the position of the brush head with respect to the teeth **100** and gingival tissue **102** during the conventional cleaning operation. As would be expected, at various times several of the bristle clusters **14** will contact the gingival tissue. The ultrasonic energy available at the bristle tips provide several beneficial results. Cavitation and/or high energy atomization is produced at the area of contact between the tooth surface and the gingival tissue enabling the removal of foreign deposits from this otherwise relatively inaccessible area. Such deposits, if not removed, are the prime cause of the several diseases of the gingival tissue which ultimately result in the premature loss of teeth. Application of ultrasonic energy in accordance with the present invention serves to remove these deposits before they accumulate and thus alleviates the cause of the difficulty.

A further benefit is bestowed on the gingival tissue itself. As is well known, stimulation of the gingival tissue by massage has been found beneficial to the overall dental health. The small amplitude, high frequency motion of the present invention is advantageous for this purpose since the limited motion avoids damage to the delicate tissue and the high frequency of occurrence provides more stimulation to blood circulation than is obtained by brushing with conventional implements.

In the foregoing discussion and in FIGS. 1A, 1B and 2, a cleaning member suitable for the application of ultrasonic energy to tooth and gingival surfaces in accordance with the invention has been indicated as conforming to conventional toothbrush construction. Thus, a brush head made up of a plurality of bristle clusters **14** is generally satisfactory for this purpose. On the other hand, inasmuch as the intensity of cavitation action depends in part upon the output area of the ultrasonically vibrating element, it is preferable in accordance with the invention to provide cleaning members having relatively extended output areas. As shown in FIG. 1B this may be accomplished by providing bristle clusters composed of a relatively large number of individual bristle filaments **14a** closely spaced to each other and having the free ends cut in the same plane, whereby each bristle cluster presents a substantially solid output surface. This construction enables the improved cavitation action to be achieved without interfering with the flexibility of the bristle filaments which contribute to the scrubbing action.

An alternative form of cleaning member construction is shown in FIG. 3 wherein the cleaning elements **20** are relatively thick, single members extending from the brush head support **12**, and having somewhat rounded tips. While not as flexible as the individual filaments **14a** shown in FIGS. 1A and 1B, the cleaning elements **20** enable somewhat better transmission of ultrasonic vibration to the tips thereof, with the result that the cavitation action thereat is increased. Such elements thereby provide a greater cavitation cleaning potential and, in presenting more ultrasonic energy than thinner filaments will generally enhance the total tooth cleaning effect.

Regardless of the precise nature of the cleaning elements employed, it is desirable in order to provide adequate cavitation action that the bristle members have a significant component of motion perpendicular to the tooth surfaces over which they pass. For this reason it has been found advantageous to mount the bristle element at an angle other than a right angle to the brush head supporting member **12**. As will be apparent from a vectorial analysis of the components of motion in the bristle clusters, taking into account the flexibility of the bristle filaments, the nearer the orientation of the bristle clusters to the direction of vibration of the brush head, the bigger the component of bristle vibration that occurs in the direction longitudinally of the bristle member. Conversely, the closer the bristle cluster is to perpendicular to the brush head, the greater the component of motion perpendicular to the direction of the bristle. To accommodate a brush head to the configuration of the human

mouth may require a compromise between the two extremes, and various intermediate angles, such as those shown in FIGS. 1A, 1B and 3 are possible which provide proper ratios of the two components of motion at the bristle tips to achieve the beneficial results of the invention. Alternatively, some or all of the bristle members may be normal to the brush head and various angular bristle orientations on the same brush head may be employed.

In FIGS. 4 through 7 there is shown an ultrasonically driven tooth cleaning implement in accordance with the principles of the present invention. As seen best in FIG. 4, the implement **10** comprises two basic elements: a brush insert **22**, and a handle element **24** for receiving the insert **22**.

The brush insert **22** is shown in cross-section view in FIG. 5. In the illustrated embodiment, the insert **22** comprises an elongated magnetostrictive element **26** formed of a plurality of thin sheets of a magnetostrictive material such as permanickel or Permendur, or any other material capable of mechanically elongating when subjected to a magnetic field. As shown in the sectional view in FIG. 7, the member **26** is fabricated of a plurality of individual plates which are insulated from each other and held tightly in stacked relation such as by rivets (not shown) extending therethrough. In view of the relative dimensions of the magnetostrictive portion **26**, it will be seen that upon insertion in a suitably oriented magnetic field, a significant elongation of the stack will occur. Consequently, upon application thereto of a magnetic field whose magnitude varies, the length of the stack **26** will similarly vary. In accordance with known principles, the magnetostrictive stack **26** is made to be of a length equal to an integral number of half-wavelengths in the material at the driving frequency. In this manner, maximum conversion of energy from the magnetic field to mechanical vibration is achieved. As noted hereinabove, other forms of electrical to mechanical transducers, e.g. piezoelectric, ferrites, may also be employed in accordance with the present invention.

Rigidly affixed to one end of the magnetostrictive element **26**, such as by welding, is a connecting member **28**. This member may be formed of any suitable material capable of supporting vibrations transmitted thereto from the magnetostrictive stack and many metals and hard plastics are suitable for this purpose. However, to operate most efficiently, the connecting member **28** should be made equal in length to an integral number of half-wavelengths in the material at the frequency of vibration. A suitable material enabling the length of the connecting member **28** to be maintained within reasonable limits is Monel, but it will be understood that other materials may also be used.

Preferably, the connecting member **28** is formed to produce at its output end **28c** an amplification of the longitudinal vibrations applied to its input end by the magnetostrictive member **26**. To effect this function, the member **28** is formed in two sections **28a** and **28b** of differing diameter. The transition from the larger to the smaller diameter occurs at a nodal point of vibration, that is, a point along a member wherein longitudinal motion is a minimum. In a uniform diameter element one-half wavelength long, such a node would occur at the quarter-wave point, half way between the ends. By locating the transition point at a nodal plane, proper acoustic impedance transformation takes place and an increased longitudinal amplitude of vibration is obtained at the output end **28c**. A more complete discussion of such acoustic impedance transformers may be found in U.S. Patent No. Re. 25,033 granted August 29, 1961 to Balamuth and Kuris for "Vibratory Machine Tool and Vibratory Abrasion Method," and assigned to the present assignee.

The brush supporting member **12** is rigidly affixed to the forward end **28c** of the connecting member such as by a screw threaded fastening. By this means, longitudinal

vibrations in the connecting body may be transmitted unimpeded to the brush head 12 and consequently to the bristles 14 mounted therein.

Surrounding the magnetostrictive stack 26 and the connecting member 28 is a generally cylindrical casing 30 formed of a suitable non-magnetic and fluid impervious material, such as plastic or aluminum. The casing 30 is structurally rigid and spaced from the peripheral surfaces of the stack 26 and connecting member 28 over substantially their entire lengths so as not to be vibrated therewith. It is tightly secured to these elements, however, at 30a by squeezing or crimping the casing 30 to grip the corners of the stack 26, as best illustrated in FIG. 7. The crimped portion 30a is selected to be at a nodal point of longitudinal motion of the stack 26 so that no longitudinal vibration is imparted to the casing 30.

At the connecting member end of the casing 30, the walls thereof are somewhat thickened to closely engage the peripheral surface of the enlarged portion 28a of the connecting member. At approximately a nodal point of longitudinal motion in the connecting member, a plurality of inserts 32 of rubber or similar resilient material are secured in the casing and extend therethrough to snugly engage mating depressions provided in the outer surface of the connecting member 28. This serves to firmly support the connecting member within the casing 30 in such a manner that no longitudinal vibration is transmitted to the casing 30. The inserts 32 and the closeness of fit between the casing 30 and the outer surface of the connecting member 28 also provide a fluid tight seal between the casing 30 and the connecting member 28.

The end of the casing 30 beyond the magnetostrictive portion 26 is thickened and provided with a transverse slot 34 extending all the way through. The base of the slot is somewhat enlarged and generally circular in cross section to engage a suitably provided pin in the handle member 24, as will be hereinafter described. The narrowed walls of the slot enable the entire insert 22 to be firmly, but readily releasably engaged in the handle member.

At its opposite end, the casing 30 is provided with a smaller diameter shoulder adapted to be engaged by the brush housing 16 which, as shown in FIG. 6, is generally cylindrical in cross section and provided with an opening along its length to allow for protrusion of the bristle members 14. The enclosure 16 may also be formed of a plastic material of high resilience, sized so as to firmly engage the reduced diameter shoulder of the casing 30. The enclosure 16 need be removed only when it is desired to replace the brush member 12, such as when the bristles 14 have been worn to the point where they are no longer effective.

It will be seen that the entire brush insert 22 is self-contained and includes only one part subject to wear, i.e., the bristles 14 in the brush head 12. The latter is arranged to be removed without difficulty and replaced with a new unit whenever necessary. It will also be observed that the insert 22 may be used in the same manner as the conventional manually actuated toothbrush should the need arise. As will become apparent hereinafter, in an implement according to the invention intended for home use by several members of a household, each member of the household would be provided with his personal brush insert 22 which he would place in the handle 24 prior to use.

The handle member is a generally cylindrical element preferably formed of an electrically insulating and fluid impervious plastic material, which is provided with a central bore 40 extending axially therethrough. The outer dimensions of the handle 24 are made such as to be comfortably held in the hand without causing fatigue.

The handle 24 is formed in two sections, a first section 42 whose outer surface forms the peripheral surface of the handle, and a second portion 44 including a tubular extension which fits within the member 42, leaving

between the members an annular space extending substantially over their entire lengths. Within this annular space is wound a coil 46 of insulated wire for establishing the magnetic field. At the rearward end of the bore in the member 42 is formed a reduced diameter portion 43 sized to snugly receive the brush insert 22. A similar portion 45 is provided at the forward end of the member 44 so that the insert 22 is firmly supported in the handle 24.

A pin 48 is mounted transversely of the bore rearwardly of the segment 43. This pin is rigidly mounted in the plastic of the member 42 and is of a diameter greater than the spacing of the walls of the slot 34 in the casing 30, but somewhat less than the diameter of the enlarged base of the slot. The resiliency of the plastic used in the housing 30 enables the brush insert 22 to be manually forced over the pin 48 by a force which is sufficient to prevent its voluntary release but which a child is capable of applying. Similarly, the insert 22 may be removed from the handle 24 with the proper amount of force.

The ends of the coil 46 are brought out through a conductor 50 and into a plug connector 52. The latter is provided with a pair of prongs 54 suitable for insertion in an appropriate source of electrical energy (not shown). An extension 56 may be cast integrally with the member 42 or added thereto to provide a strain relief for the connecting lead 50.

A thumb switch 58 may be provided on the exterior of the handle 24 for opening or closing the coil circuit to control the supply of power to the cleaning implement. Alternatively, switch means (not shown) may be provided within the bore 40 to be actuated upon insertion of a brush insert 22 and conversely deactivated upon removal of the insert. By such means, power waste is minimized.

The complete assembly for use in the home would include, in addition to the apparatus disclosed in FIGS. 4 and 5, a suitable source of alternating electrical energy and D.C. polarizing current. Such a source would include, for example, a transistorized oscillator capable of producing electrical oscillation at a frequency in the ultrasonic range e.g., between 15,000 and 40,000 c.p.s. Various types of such oscillators are known and it is not believed necessary to describe the details herein.

Electrical oscillations and direct current from the source are coupled via the connector 52 and the lead 50 to the coil 46 in the handle 24. There is thus established in the bore 40 of the handle a magnetic field whose magnitude changes at an ultrasonic rate. Upon insertion of the brush insert 22, the magnetostrictive portion thereof 26 is positioned within the magnetic field and in well known manner, provides a mechanical longitudinal vibration at the frequency of the magnetic field. This vibration is transmitted via the connecting member 28 to the brush head 12 and the bristles 14. Since the casing 30 is isolated from the longitudinal motion of magnetostrictive stack 26 and the connecting member 28, no vibrations are coupled therethrough and no damping thereof occurs when the assembly is held in the hand of the user.

Furthermore, inasmuch as relatively low power is required and the average brushing procedure takes only a matter of minutes, the heat generated in the magnetostrictive stack 26 is insufficient to cause any damage to the apparatus itself or to provide any discomfort to the user. The diameter of the conductor used for the coil 46 is made relatively large to minimize heat generation resulting from I²R losses.

From the foregoing, it will be evident that the application of ultrasonic energy to tooth and gingival surfaces is effective to provide significantly improved cleaning action, and, if employed for regular dental care in the home, will result in maintenance of greater dental health than is possible utilizing conventional toothbrushing implements.

The ability of the application of ultrasonic energy to remove foreign deposits on a massive scale has been demonstrated by the professional acceptance of the cleaning implement described in the above-mentioned Patent No. 3,076,904. That apparatus, intended only for use by skilled dentists or dental technicians in the dental office, utilizes a single hard, edged metal tool driven by high energy ultrasonic vibrations for the purpose of performing complex periodontal treatment of gums and teeth as well as for professional prophylaxis. Such an implement, in the hands of unskilled persons, could severely damage both the teeth and the tender gingival tissue.

In accordance with the present invention, however, relatively low frequency, small amplitude vibrations are employed to drive a brushing implement which, as in the case of the conventional toothbrush, is made up of a material soft with respect to the tooth surfaces. The various plastics such as nylon, or natural bristles, are suitable for this purpose. While it is evident that a single use of the present invention will provide the dramatic cleaning results available from the professional equipment described in the aforementioned patent, its continual regular use will significantly lessen the necessity for such professional treatment. Moreover, the use of relatively soft bristle materials in combination with low energy ultrasonic vibrations renders the use of the invention perfectly safe, whereby it may be regularly employed by average persons without any special training or skill. Extended periods of application of ultrasonic energy to the tooth and gingival surfaces in accordance with the present invention will have no deleterious effect on these surfaces.

In addition to the superior cleaning action provided by the invention, several auxiliary benefits of the ultrasonic action have been noted. The micro-massage of the gingival tissue, discussed hereinabove, contributes significantly to overall dental health. The ultrasonic action also results in partial sterilization of bacterial-laden areas of the mouth and provides more intimate application of chemical or other agents that may be contained in a dentifrice, if employed by the user.

Cavitation action requires for its support a substantial solid film of a liquid capable of supporting cavitation between the tip of the cleaning member and the tooth surface to be cleaned. This fluid film may be provided by the natural fluids in the mouth, emission of which is stimulated during the brushing procedure, or if desired, additional fluid, such as plain water, may be taken into the mouth prior to the beginning of the brushing procedure. The use of a dentifrice is likewise optional. The combination of the cleaning phenomena provided in accordance with the invention renders the addition of an abrasive such as is found in many commercial dentifrices, unnecessary. However, the use of the pleasant tasting and scented liquid, paste or powder may be desirable for aesthetic reasons.

It will be seen therefore, that in accordance with the invention a method of utilizing ultrasonic energy for improved dental hygienic care is provided, together with a novel form of apparatus by means of which the process may be carried out. Although only one form of the latter has been illustrated, it will be recognized that many modifications thereof may be made without departing from the spirit of the invention. For example, the shape and configuration of the handle member 24 may be changed radically from that shown and a different form of engaging means may be provided in lieu of the pin and slot device illustrated. Moreover, the handle member 24 may be enlarged to accommodate a transistorized oscillatory power supply instead of merely including a connection to an external source. In the same way, the bristle elements 14 may take various configurations ranging from cavitation bristles as shown to relatively broad area elements known as stimulents. Although a magnetostrictive embodiment has been shown, the broad principles

of the invention are equally applicable to other forms of electroacoustic vibration generation, e.g., piezoelectric or electrostrictive conversion.

Accordingly, the invention is not intended to be limited except as set forth in the appended claims.

We claim:

1. A method of removing surface, interproximal and gum line foreign deposits from teeth comprising the steps of positioning adjacent the teeth to be cleaned a cleaning member of a material soft relative to the tooth surfaces and capable of supporting vibrations in the ultrasonic range, inducing vibrations in said member at a frequency in the ultrasonic range, and moving said ultrasonically vibrating cleaning member relative to said teeth such that it assumes positions in which it is randomly divided between actual contact with and displacement from the surfaces of said teeth.

2. A method of removing surface, interproximal and gum line foreign deposits from teeth comprising the steps of establishing a fluid film on the tooth surfaces, positioning adjacent the teeth to be cleaned a multi-element cleaning member of a material soft relative to the tooth surfaces and capable of supporting vibrations in the ultrasonic range, inducing variations in the elements of said member at a frequency in the ultrasonic range, and moving said ultrasonically vibrating cleaning member relative to said teeth such that the elements thereof assume positions in which they are randomly divided between actual contact with and displacement from the surfaces of said teeth.

3. A method of removing surface, interproximal and gum line foreign deposits from teeth comprising the steps of positioning adjacent the teeth to be cleaned a multi-element cleaning member of a material soft relative to the tooth surfaces and capable of supporting vibrations in the ultrasonic range, inducing in said elements ultrasonic vibrations having orthogonally related components of motion, and moving said ultrasonically vibrating cleaning member relative to said teeth such that the elements thereof assume positions in which they are randomly divided between actual contact with and displacement from the surfaces of said teeth.

4. A method of cleaning teeth in the human mouth suitable for regular personal hygienic care, comprising the steps of positioning a brush member in the mouth adjacent the teeth to be cleaned in the presence of a dentifrice, manually moving said brush element across the surfaces of the teeth, and inducing vibrations at an ultrasonic rate in the bristles of the brush while so moving.

5. A method of cleaning teeth in the human mouth suitable for regular personal hygienic care, comprising the steps of positioning a brush member in the mouth adjacent the teeth to be cleaned, manually moving said brush element across the surfaces of the teeth while in relatively light contact therewith, and inducing vibrations at an ultrasonic rate in the bristles of the brush while so moving.

6. A method of cleaning teeth in the human mouth suitable for regular personal hygienic care, comprising the steps of positioning a brush member in the mouth adjacent the teeth to be cleaned, manually moving said brush element across the surfaces of said teeth and over interproximal and gingival areas with said brush element in relatively light contact with said tooth and gingival surfaces, and inducing vibrations at an ultrasonic rate in the bristles of the brush member while so moving, the amplitude of said vibrations being insufficient to cause injury to gingival tissue.

7. A method of cleaning teeth in the human mouth suitable for regular personal hygienic care, comprising the steps of positioning a brush member in the mouth adjacent the teeth to be cleaned, manually moving said brush element across the surfaces of said teeth and over interproximal and gingival areas with said brush element in relatively light contact with said tooth and gingival sur-

faces, and inducing vibrations at an ultrasonic rate in the bristles of the brush member while so moving, thereby to effect scrubbing at an ultrasonic rate on surfaces contacted by said vibrating bristles and to promote cavitation action at surfaces spaced from said bristles.

8. A method of cleaning teeth in the human mouth suitable for regular personal hygienic care, comprising the steps of positioning a brush member in the mouth adjacent the teeth to be cleaned, manually moving said brush element across the surfaces of the teeth, and inducing vibrations in said bristles at a frequency between about 15,000 to about 40,000 cycles per second and of an amplitude such that the major component of motion of said bristles is approximately .001 inch.

9. A method of removing surface, interproximal and gum line foreign deposits from teeth in the human mouth comprising the steps of positioning a brush member adjacent the teeth to be cleaned, manually moving said brush element across the surfaces of said teeth to randomly shift the bristles thereof between positions in contact with and spaced from said tooth surfaces, and inducing in the bristles of said brush member vibrations at an ultrasonic rate, whereby there may concomitantly result a scrubbing action at an ultrasonic rate on the tooth surfaces when in contact with said bristles and cavitation action between said bristles and said tooth surfaces when said bristles are displaced therefrom.

10. Apparatus for use in personal dental hygienic care comprising, a cleaning member of a material soft relative to human tooth surfaces and capable of supporting vibrations in the ultrasonic range, said member being adapted to be received within the human mouth and moved across tooth and gingival surfaces, means adapted to be held in the hand for generating mechanical vibrations at an ultrasonic rate, and means in said vibration generating means for supporting said cleaning member and inducing ultrasonic vibrations therein.

11. Apparatus for use in personal dental hygienic care comprising, a cleaning member of a material soft relative to human tooth surfaces and capable of supporting vibrations in the ultrasonic range, said member being adapted to be received within the human mouth and moved across tooth and gingival surfaces, transducer means adapted to be held in the hand for converting electrical energy into mechanical vibrations at an ultrasonic rate, and means in said transducer for supporting said cleaning member and inducing ultrasonic vibrations therein.

12. Apparatus for use in personal dental hygienic care comprising, a cleaning member having a plurality of individual cleaning elements of a material soft relative to human tooth surfaces and capable of supporting vibrations in the ultrasonic range, said member being adapted to be received within the human mouth and the elements thereof moved across the tooth and gingival surfaces, transducer means adapted to be held in the hand for converting electrical energy into mechanical vibrations at an ultrasonic rate, and means in said transducer for supporting said cleaning member and inducing ultrasonic vibrations in said cleaning elements.

13. Apparatus for use in personal dental hygienic care comprising, a cleaning member of a material soft relative to human tooth surfaces and capable of supporting vibrations in the ultrasonic range, said member being adapted to be received within the human mouth and moved across tooth and gingival surfaces, electroacoustic transducer means including a first member adapted to be held in the hand and to be supplied with alternating electrical energy at a frequency in the ultrasonic range, a second member responsive to alternating electrical energy to mechanically vibrate at the frequency of said energy, means on said second member to support said cleaning member and impart vibrations thereto, and means in said first member for receiving said second member in readily releasable fashion, said second member converting the electrical energy supplied to said first member into mechanical vi-

brations when received therein, whereby ultrasonic vibrations are induced in said cleaning member.

14. Apparatus for use in personal dental hygienic care comprising, a cleaning member of a material soft relative to human tooth surfaces and capable of supporting vibrations in the ultrasonic range, said member being adapted to be received within the human mouth and moved across tooth and gingival surfaces, an elongated member formed at least in part of a magnetostrictive material, means to couple said cleaning member to one end of said elongated member, an additional member adapted to be held in the hand and including coil means for creating an alternating magnetic field at the frequency of alternating current signals applied thereto, said additional means further including means to releasably receive said elongated member such that said magnetostrictive portion thereof is disposed in said magnetic field, whereby upon application of alternating current signals to said coil, said elongated member mechanically vibrates in a longitudinal direction and vibrations are induced in said cleaning member.

15. Apparatus for use in personal dental hygienic care comprising, a brush member adapted to be received within the human mouth and moved across tooth and gingival surfaces, an elongated member formed at least in part of a magnetostrictive material, means to rigidly couple said brush member to one end of said elongated member, a casing of non-magnetic material enclosing at least said magnetostrictive portion of said member in fluid-tight manner, an additional member adapted to be held in the hand and including coil means for creating an alternating magnetic field at the frequency of alternating electrical signals applied thereto, said additional means further including means to releasably receive said elongated member such that said magnetostrictive portion thereof is disposed in said magnetic field, whereby upon application of alternating electrical signals to said coil, said elongated member mechanically vibrates in a longitudinal direction and vibrations are induced in the bristles of said brush member.

16. Apparatus for use in personal dental hygienic care comprising, a brush member adapted to be received within the human mouth and moved across tooth and gingival surfaces, an elongated member formed at least in part of an electroacoustic transducing material, means to rigidly couple said brush member to one end of said elongated member, an additional member adapted to be held in the hand and of a length shorter than said elongated member, an opening in said additional member adapted to receive at least the electroacoustic transducing portion of said elongated member, means in said opening to engage said elongated member in a readily releasable fashion, energy supply means in said additional member adjacent said opening, and means to connect alternating electrical signals to said energy supply means for coupling to said electroacoustic transducing portion, whereby mechanical vibrations at the frequency of said alternating signals are induced in said elongated member and said brush member.

17. Apparatus for use in personal dental hygienic care comprising, a brush member adapted to be received within the human mouth and moved across tooth and gingival surfaces, an elongated member formed at least in part of a magnetostrictive material, means to rigidly couple said brush member to one end of said elongated member, an additional member of electrically insulating material adapted to be held in the hand and of a length shorter than said elongated member, an elongated bore in said additional member adapted to receive at least the magnetostrictive portion of said elongated member, means in said bore to engage said elongated member in readily releasable fashion, coil means embedded in said additional member and surrounding said bore, and means to supply alternating electrical signals to said coil means to establish an alternating magnetic field in said bore, whereby

mechanical vibrations at the frequency of said alternating signals are induced in said elongated member and said brush member.

18. Apparatus for use in personal dental hygiene care comprising, a brush member adapted to be received within the human mouth and moved across tooth and gingival surfaces, an elongated member formed at least in part of a magnetostrictive material, means to rigidly couple said brush member to one end of said elongated member, a casing of non-magnetic material enclosing at least said magnetostrictive portion of said member in fluid-tight manner, an additional member of electrically insulating material adapted to be held in the hand and of a length shorter than said elongated member, an elongated bore in said additional member adapted to receive at least the magnetostrictive portion of said elongated member, means in said bore to engage said elongated member in readily releasable fashion, coil means embedded in said additional member and surrounding said bore, and means to supply alternating electrical signals to said coil means to establish an alternating magneto field in said bore, whereby mechanical vibrations at the frequency of said alternating signals are induced in said elongated member and said brush member.

19. A personal brush insert for use with an ultrasonic dental cleaning implement having a handle member including coil means adapted to be energized from a source of alternating electrical signals and means to engage the insert in readily releasable fashion, said brush insert comprising, a brush member adapted to be received within the human mouth and moved across tooth and gingival surfaces, an elongated member of magnetostrictive material having a length equal substantially to an integral number of quarter wavelengths in the material at the frequency of said alternating signals, a connecting member of vibration transmitting material fixed at one end to one end of said magnetostrictive member and having the other end adapted to rigidly support said brush mem-

ber in vibration transmitting relationship, said connecting member being of a length substantially equal to an integral number of quarter wavelengths in the material at the frequency of said alternating frequency, and a fluid impervious casing enclosing at least said magnetostrictive member.

20. A personal brush insert according to claim 19, wherein said casing is spaced from said magnetostrictive member over substantially its entire surface and is fastened thereto at a point along the length of said magnetostrictive member at which a node of longitudinal vibration occurs.

21. A personal brush insert according to claim 20 in which said casing also encloses said connecting member in spaced relation thereto and a fluid-tight seal is provided between said casing and said connecting member at a point along said connecting member at which a node of longitudinal motion occurs.

22. A personal brush insert according to claim 21 in which said casing is formed of a non-magnetic material and is provided at its end remote from said brush member with a slot adapted to engage a pin in said handle member in readily releasable fashion.

23. A personal brush insert according to claim 19 in which said connecting member comprises an acoustic impedance transformer for amplifying vibrations provided by said magnetostrictive member.

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L. W. TRAPP, *Primary Examiner.*

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,375,820

April 2, 1968

Arthur Kuris et al.

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 10, line 16, after "to" insert -- be --. Column 11, line 20, after "will" insert -- not --. Column 12, line 24, "variations" should read -- vibrations --; line 44, "hygenic" should read -- hygienic --. Column 15, line 4, "hygene" should read -- hygienic --.

Signed and sealed this 12th day of August 1969.

(SEAL)

Attest:

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Attesting Officer

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Commissioner of Patents