ABSTRACT OF THE DISCLOSURE

A piezoelectric dental cleaning device comprising a tubular piezoelectric crystal supported within a handle-like hollow casing by a spacer which centers said crystal and provides an elongated spacing annulus between the inner wall of the casing and the outer wall of the crystal with a seal near the lower end of the crystal, a working tip having a working end mechanically secured to the upper end of said crystal to form a compound resonator there-with, means for effecting longitudinal ultrasonic vibrations of said crystal and means for delivering coolant into said spacing annulus and directing it outwardly thereof in a region adjacent the working end of the tip to flush debris loosened by ultrasonic vibration of said working end of said tip.

This invention relates to a cleaning device utilizing ultrasonic vibrations for dislodging debris, for example, from a tooth, including tartar, stain, loose particles, calculi, etc.

In general, apparatus embodying the principles of the invention comprises a tip mounted in a hand piece, the tip being mechanically coupled to a piezoelectric crystal so as to form with it a compound ultrasonic resonator. The vibratory action of the crystal is transmitted to the tip by directing mechanical coupling. The crystal is so formed as to provide longitudinal ultrasonic vibrations when it is activated by high frequency electrical impulses and the resultant ultrasonic vibrations are transmitted directly without reverberatory vibrations through the tip to the point of use. The crystal utilized is of tubular configuration made preferably of lead zirconate and/or lead titanate ceramic material which is so formed that it has the quality of expanding and contracting longitudinally at ultrasonic frequencies and is joined end to end to the tip by an epoxy cement or other means so that the ultrasonic tip movements are directly related to the longitudinal expansion and contraction of the activated crystal. While the latter may be designed to be operated at frequencies from 25,000 c.p.s. upwards to 45,000 c.p.s., for dental applications, such frequencies usually will not exceed 35,000 c.p.s. Since each crystal must be designed for a required frequency, the crystal and attached tip constitute a matched pair and form said compound resonator. Provision is made in the hand piece for supporting and retaining the crystal and tip. In addition, a water duct in conjunction with the hand piece and tip is provided for cooling the crystal as well as ejecting a stream of water adjacent the tip during use.

Use of magnetostrictive activation of responsive metal alloys provides ultrasonic vibrational motion of a cleaning tip is known in the art. However, a major difficulty in prior art devices is the consequent production of reverberatory vibrations during use that may produce undesirable effects.

Principal objects and features of this invention are, therefore, the provision of a simply constructed lightweight ultrasonic cleaning device having particular adaptability for dental use utilizing ultrasonic vibrations of a cleaning tip which are generated in such a way that they are directly transmitted to the tip without any undesirable reverberatory vibrations.

Other objects and features of the invention are the provision of a mechanically simple and effective ultrasonic cleaning device utilizing a compound resonator including a tip and a piezoelectric crystal. The source of ultrasonic vibrations may be manufactured at relatively low cost and which will be trouble free and long-lasting in operation and free of reverberatory vibrations.

Further objects and features of the invention will become apparent from the following specifications and the accompanying drawings, wherein:

FIG. 1 is a longitudinal sectional view of a device embodying the invention;

FIG. 2 is an enlarged fragmentary section of the crystal and tip member junction; and

FIG. 3 is an enlarged fragmentary section of the crystal.

Referring now to the drawings, and in particular FIG. 1, the reference character 10 denotes generally a cleaning device including an outer insulated casing 11 in the form of a tubular hand piece for convenient manipulation of an operator. This casing 11 may be of plastic or any other suitable electrical insulating material and includes a head end 12 provided with an orifice or restricted passageway 13 through which the vibratory tip 14 of the device projects. A seal in the form of an O-ring 15 of rubber or the like is mounted in the orifice 13 about the tip 14 to center the tip and to preclude entry or exit of water or moist atmosphere to or from the inside of the casing 11 via said orifice 13. The tip 14 is preferably of metal, e.g., stainless steel or beryllium-copper being a solid rod 14a in the major portion of its length protruding beyond the orifice 13 and terminating in an appropriately shaped outer working end 14b that is to be applied to teeth or other elements that are to be cleaned.

Internally of the orifice 13 and within said casing 11, the tip has a solid base portion 16 that flares outwardly for mounting on one end of a piezoelectric crystal 17. (See also FIG. 2). This crystal 17 is of tubular shape and in the embodiment shown comprises a lead zirconate-lead titanate ceramic crystal which is formed so as to be capable of ultrasonic vibrational activity in its longitudinal direction when activated by high frequency electrical impulses delivered to it as will be described.

The flared base end 16 of said tip 14 is mounted over and is mechanically joined at 18 to said end of said crystal 17 by a hardening cement 17a of, for example, the epoxy type which, upon setting, becomes rigid and provides a solid direct mechanical coupling between the said tip portion 16 and said end of said crystal 17 so that ultrasonic longitudinal vibrations of the latter are directly transmitted to the tip 14 without reverberatory vibrations and the tip and crystal become, in fact, a compound resonator.

As shown in FIG. 2 the base 16 has a depending skirt portion 19 which extends downwardly over the upper end 20 of crystal 17 and a recessed portion portion 21 is provided in the bottom 22 of base 16 to receive the epoxy cement 17a. Rubber plug member 23 closes the central passageway 24 at end 20 of the crystal.

Crystal 17 is mounted within handle 11 in axial alignment therewith by spacer means or ring member 25 of cylindrical or other suitable ceramic material which centers crystal 17 and provides elongated annulus 26 between crystal 17 and the interior wall 27 of handle 11. Rubber washer 28 provides a fluid-tight seal for annulus 26 at the lower end 29 of crystal 17.

On the side surfaces 25a and 25b of spacer member 25 is a thin film of rubber or the like providing a sealant between the adjoining surfaces of the ring member 25 and the crystal 17 and the casing 11. The rubber film also
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provides a shock absorbent means to keep vibrations from being transmitted to casing 11. Water tubing 30, interconnected at its inlet end 31 with water source 32, extends at an intermediate portion along the outer surface 33 of handle 11 and then extends through the wall 12 thereof into communication with annulus 26. At the upper or working end 34 of handle 11 another length of water tubing 35 extends through wall 12 and delivers water from annulus 26 to outlet end 19a at a point adjacent outer end 14b of tip 14. Water delivered by flexible tubing 30 will pass longitudinally through annulus 26, upwardly beyond crystal 17 and base member 16 for delivery through outlet tubing 34 to the region being operated on by the working end 14b of tip 14.

In this manner the water provides both a cooling medium for crystal 17 and flushing water at the tip member 14.

Electrical ultrasonic oscillator 36 is interconnected to crystal 17 by wires 37, 38 connected respectively to inner and outer walls 39, 40 of crystal 17 by soldering or the like. The crystal 17 is provided on its wall surfaces with an electrically conductive silver coating 41 of approximately 0.0015 inch thickness which extends to within about ¼ inch of the ends on inner wall 39 and to within about ¼ inch on outer wall 40. Such coating is applied by electrodeposition or any other conventional process. After the abovedescribed connection is effected between crystal 17 and wires 37, 38 during assembly the assembly is then sprayed with a protective film 42 of nylon, latex rubber or the like.

Oscillating electric power delivered to said electrodes 37 and 38 from the oscillator 36 will provide the desired piezoelectric effect and ultrasonic longitudinal vibration of said crystal 17 and tip 14. For example at an operating frequency of about 28,900 c.p.s. the applied voltage to the crystal would be in the range of about 55 to 200 volts R.F. (300 watts), the voltage being adjusted depending on the power output desired at the tip.

Electrode 37 and inner wall 46 of crystal 17 are preferably connected to the “hot” side of the oscillator circuit 36 and electrode 38 and outer wall 47 to the “neutral” side for greater protection of the user of the device from any malfunction which would result in electrical shock to the user.

The termination of the conductive coating 41 on the inner wall 39, rubber plug 23, recessed portion 21 of base 16 and epoxy cement 17a all combine to insulate the device sufficiently to prevent voltage breakdown between the inside or “hot” electrode 37 and inner wall 46 on the one hand, and the neutral electrode 38, outer wall 47 and base member 16 on the other hand. The disclosed design provides protection up to a breakdown voltage of about 20,000 volts.

As noted above, when the ultrasonic vibrations are created in crystal 17, these are transmitted directly to the tip 14 at its junction 18 with the latter so that the tip 14 likewise has ultrasonic vibrations transmitted to it, so that when its working end 14b is applied to a tooth or other surface to be cleaned these vibrations serve to liberate accumulated dirt on such surfaces which latter is flushed away as debris by the water spray delivered by the outer end 19a of pipe 34.

The crystal 17 of tubular form consists of a lead zirconate-lead titanate ceramic having the unique quality of expanding and contracting in longitudinal direction when excited by high frequency electrical oscillations as shown. While the crystals may be designed to produce this effect with oscillations at from 25,000 c.p.s. to 45,000 c.p.s., preferably, for dental application, the response will not exceed 35,000 c.p.s. Each crystal 17 is designed to respond more or less to a specific frequency and the tip 14 which is secured thereto as described provides with it a matched pair providing a compound resonator responsive to the selected frequency.

Preferably, the contact between tip 14 and the O-ring 15 is at an antinode of said tip in its oscillatory motion so as to prevent interference with the amplitudes of its response.

In magnetostrictive devices of the prior art the arrangement usually involves a half-wave length for the magnetostrictive component and a half-wave length for the tip assembly. In devices according to the present invention it has been found that the tip assembly, i.e. from the operative end of the tip to the junction with the crystal, provides best results when it is about 26% shorter than the calculated resonant length. Consequently the overall length of the present device is considerably shorter than prior art devices. Furthermore the present design delivers pure ultrasonic longitudinal vibratory motion from the crystal to the working tip end.

The nominal electro-mechanical properties of suitable piezoelectric ceramic crystals of lead zirconate-lead titanate ceramic tubes both 28.17 kc. long, .375 inch outer diameter, .104 inch wall thickness useful in practicing the invention are as follows:

<table>
<thead>
<tr>
<th>Crystal 1</th>
<th>Crystal 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Strontium additve)</td>
<td>(Niobium additive)</td>
</tr>
<tr>
<td>Ke</td>
<td>.69</td>
</tr>
<tr>
<td>Kt</td>
<td>.66</td>
</tr>
<tr>
<td>Ec</td>
<td>.22</td>
</tr>
<tr>
<td>Piezoelectric Constants:</td>
<td></td>
</tr>
<tr>
<td>Dv (meters per volt)</td>
<td>26X10^-12</td>
</tr>
<tr>
<td>Du (meters per volt)</td>
<td>-130X10^-12</td>
</tr>
<tr>
<td>Gv (volts per Newton)</td>
<td>2X10^-6</td>
</tr>
<tr>
<td>Gu (volt meters per Newton)</td>
<td>-11X10^-6</td>
</tr>
<tr>
<td>Delecrtic Constant, Ks</td>
<td>1,800</td>
</tr>
<tr>
<td>Frequency Constant (cycle-per-second)</td>
<td>2.100</td>
</tr>
<tr>
<td>Thickness</td>
<td>1,500</td>
</tr>
<tr>
<td>Elastic Constants, gm/c cm^2</td>
<td>8,2X10^-10</td>
</tr>
<tr>
<td>Density, gm/cm^3</td>
<td>6.6</td>
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<tr>
<td>Mechanical Q</td>
<td>7.5</td>
</tr>
<tr>
<td>Curie Point, °C</td>
<td>325</td>
</tr>
</tbody>
</table>

Electrodes or wires 37, 38 and water inlet tubing 30 extend through base 43 of handle 11 and are contained within outer casing or tube 44 which is secured to handle 11 by any conventional clamping means 45.

Crystal 17 can be electrically energized to have vibratory components in other than longitudinal directions to provide various mechanical effects at the tip as desired. This would be accomplished by changing the excitation frequency. In addition the location of applying the voltage to the crystal can be utilized to produce different effects. For example by applying the voltage across opposite ends of the crystal produces a torsional effect. Another factor of crystal operation is the relative extent of crystal surface coverage by the silver coating. By flattening the tip and making the width and thickness of the tip approximately equal one can achieve lateral movement of the outer tip end and consequently the pattern of tip movement can be altered by adjustment of the tip design if other than pure longitudinal or axial motion of the tip is desired.

While specific embodiments have been disclosed, variations within the scope of the present disclosure may be possible within the skill of the art. There is no intention of limitation to the exact disclosure herein presented.

What is claimed is:

1. A piezoelectric dental cleaning device comprising a tubular hand piece, a tubular piezoelectric crystal, said hand piece having a head and provided with a restricted orifice, means for supporting said crystal within said hand piece and in spaced relationship to define an annular space upwardly of the innermost end of said tubular crystal and means for sealing said annular space off above said last-named end, a cleaning tip having a working end and a solid outwardly facing base portion and means for fixedly
securing said base portion to the outermost end of said crystal, said tip having a solid rod portion terminating in said working end and projecting from said base portion outwardly through said orifice, means adjacent the orifice to center said rod portion therein and also to provide a seal at said orifice, said means for fixedly securing said tip to said crystal comprising an epoxy cement, means for effecting longitudinal ultrasonic vibration of said crystal comprising a high frequency electric oscillator, and means for circulating cooling liquid about said crystal and ejecting it adjacent the working end of said tip onto a surface being treated thereby to effect a flushing and cooling action on said surface.

2. A piezoelectric cleaning device according to claim 1, including fluid conduit means passing around said base portion of said tip and outwardly of said tip and terminating in an open outlet end in proximity to said working portion of said tip, the other end of said conduit means being secured in the first-named end of said crystal tube, and means for delivering fluid to said hand piece for passage in said annular space around said crystal tube outwardly of said outlet end to flush debris loosened from such surface as a result of longitudinal ultrasonic vibration of said tip and crystal tube, said fluid in its passage around said crystal tube acting as a coolant therefor, a pair of electrodes respectively applied to inner and outer portions of said crystal tube and electrical conductor means connected to said electrodes and passing outwardly of said hand piece and connected to said high frequency electric oscillator.

3. A piezoelectric cleaning device according to claim 2 wherein said hand piece and said mounting means are insulated relative to said electrodes and wherein said tip is of metal.

4. A piezoelectric cleaning device according to claim 1, wherein said piezoelectric crystal is comprised of at least one of the group of materials consisting of lead zirconate and lead titanate ceramic crystals dimensioned to provide longitudinal ultrasonic vibrations at frequencies ranging from about 25,000 to about 45,000 c.p.s.

5. An ultrasonic dental cleaning device comprising an insulated tubular handle having a tapered working end defining a constricted passageway, a tubular ceramic crystal axially disposed within said handle at an intermediate portion thereof and having an outer diameter and length substantially less than the inner diameter and length respectively of said handle, peripheral spacer means interspersed between said crystal and said handle fixedly to mount said crystal in said handle and define an elongated annular space therebetween, washer means adjacent said spacer means to provide a fluid tight seal at the inner end of said annular space remote from said working end, a metallic tip member extending from said working end of said handle and having an enlarged flared base member joined to the adjacent end of said crystal and being dimensioned to define an extension of said annular space to said working end, an intermediate portion of said tip member disposed in said constricted passageway, O-ring means disposed in said passageway for providing a fluid tight seal between said intermediate portion of said tip member and said handle, said ring means making contact with said intermediate portion at an anode, fluid conduit inlet means affixed to the base of said handle and communicating with said annular space adjacent said crystal, and fluid conduit outlet means extending from said annular space adjacent said working end and having an outer end terminating adjacent the outer end of said tip member, a pair of electrical conductor means connected to opposed inner and outer surfaces of said crystal and adapted for interconnection with ultrasonic generator means, and said fluid conduit inlet means adapted for interconnection with fluid supply means.

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J. D. MILLER, Primary Examiner.

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