COILED WIRE SPRING APPLIANCES FOR USE IN ORTHODONTICS

Original Filed April 17, 1967 5 Sheets-Sheet 1

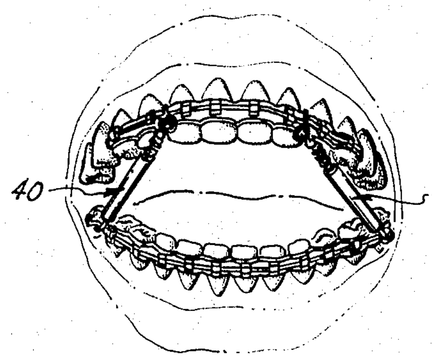

Fig. 1.

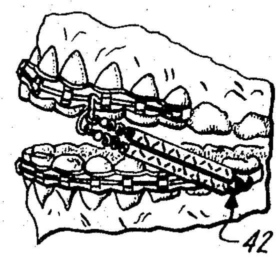

Fig. 2.

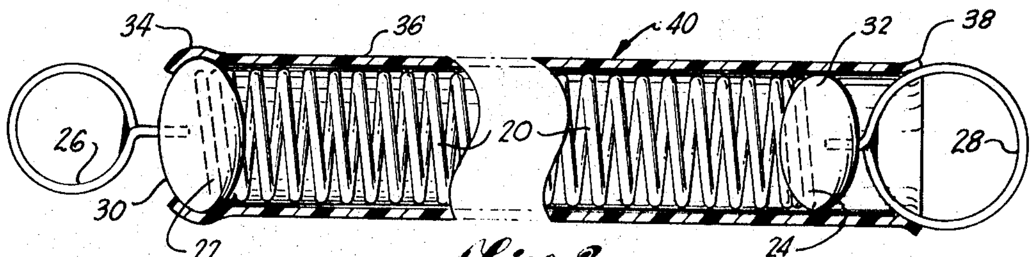

Fig. 3.

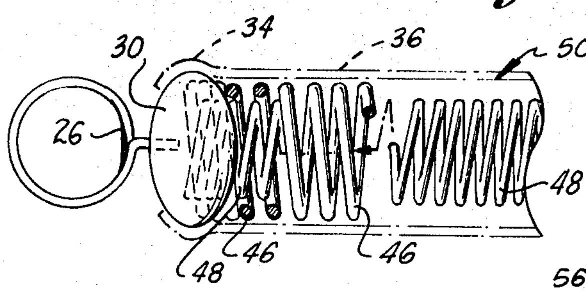

Fig. 4.

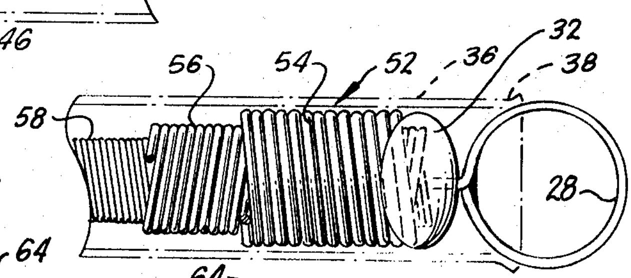

Fig. 5.

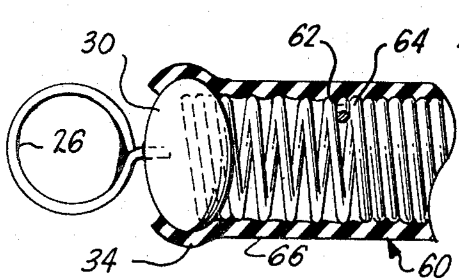

Fig. 6.

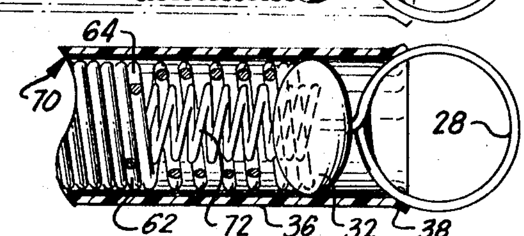

Fig. 7.

INVENTOR.
MACLAY M. ARMSTRONG
BY
Roy Mattern Jr.
ATTORNEY

COILED WIRE SPRING APPLIANCES FOR USE IN ORTHODONTICS

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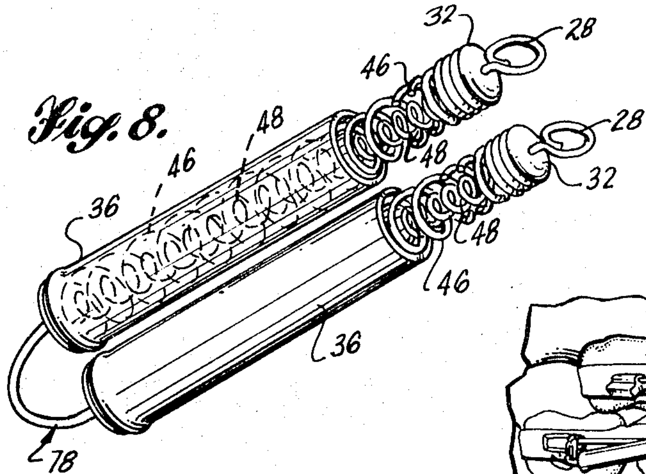

Fig. 8.

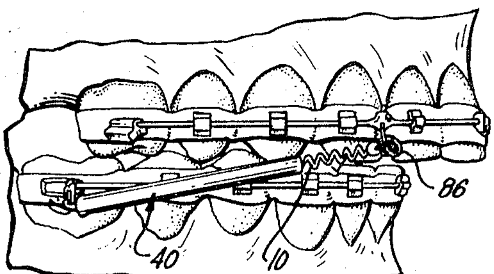

Fig. 9.

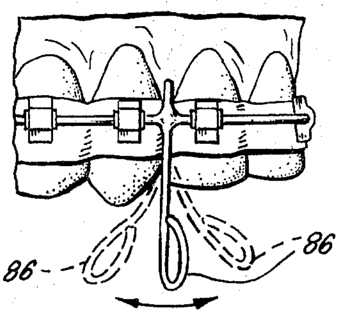

Fig. 10.

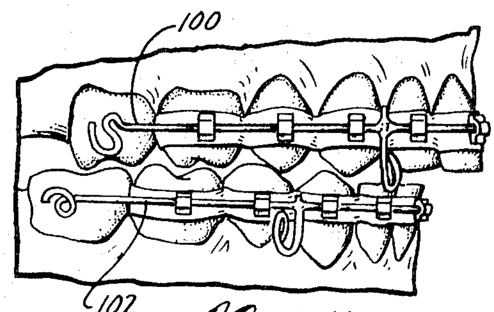

Fig. 11.

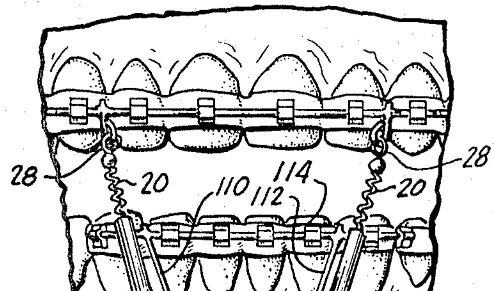

Fig. 12

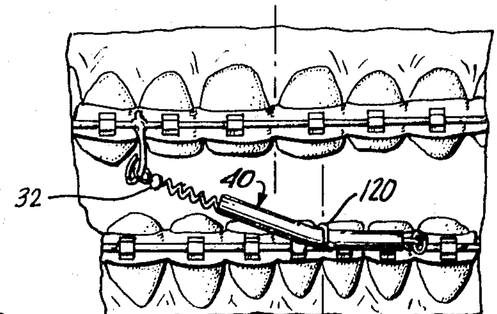

Fig. 13

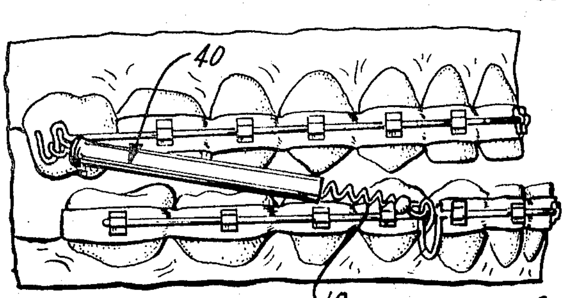

Fig. 14.

INVENTOR.
MACLAY M. ARMSTRONG

BY

Roy Mattern Jr.

ATTORNEY

COILED WIRE SPRING APPLIANCES FOR USE IN ORTHODONTICS

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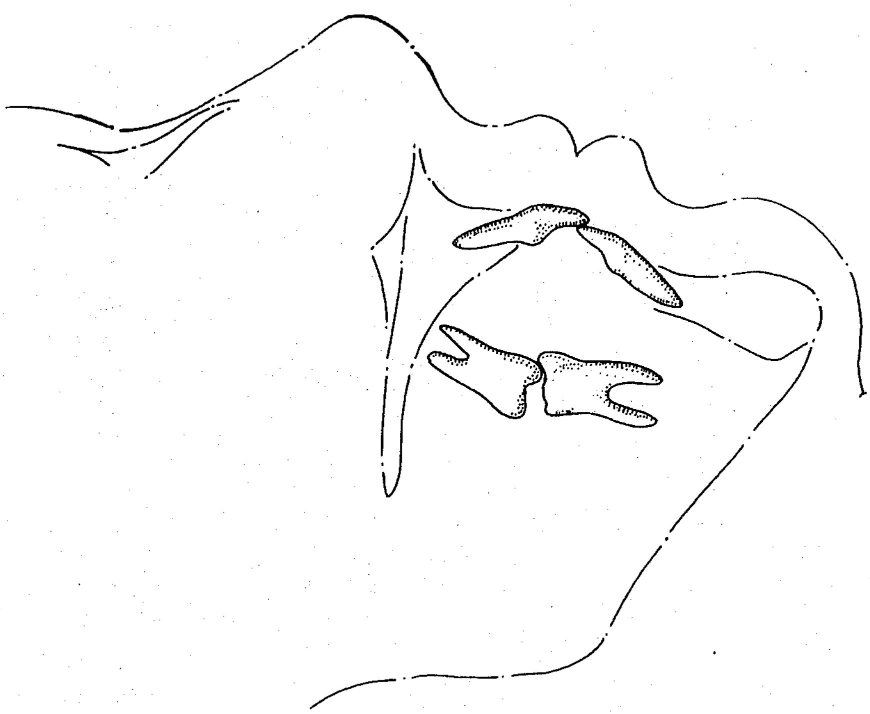

Fig. 16.

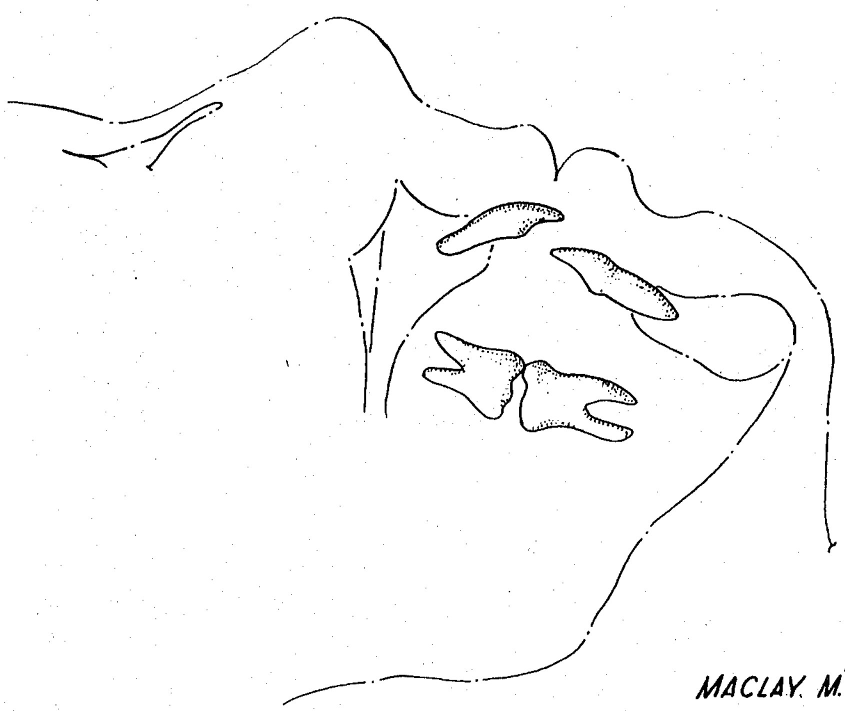

Fig. 15.

INVENTOR.
MACLAY M. ARMSTRONG
BY Roy Mattern Jr.
ATTORNEY

COILED WIRE SPRING APPLIANCES FOR USE IN ORTHODONTICS

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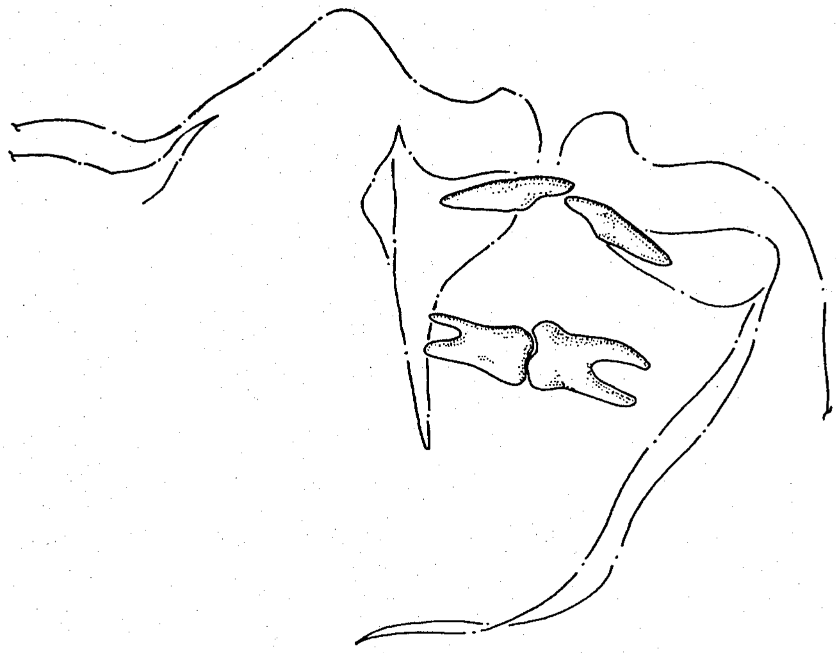

Fig. 18.

Fig. 17.

INVENTOR.
MACLAY M. ARMSTRONG
BY Roy Mattern Jr.
ATTORNEY

COILED WIRE SPRING APPLIANCES FOR USE IN ORTHODONTICS

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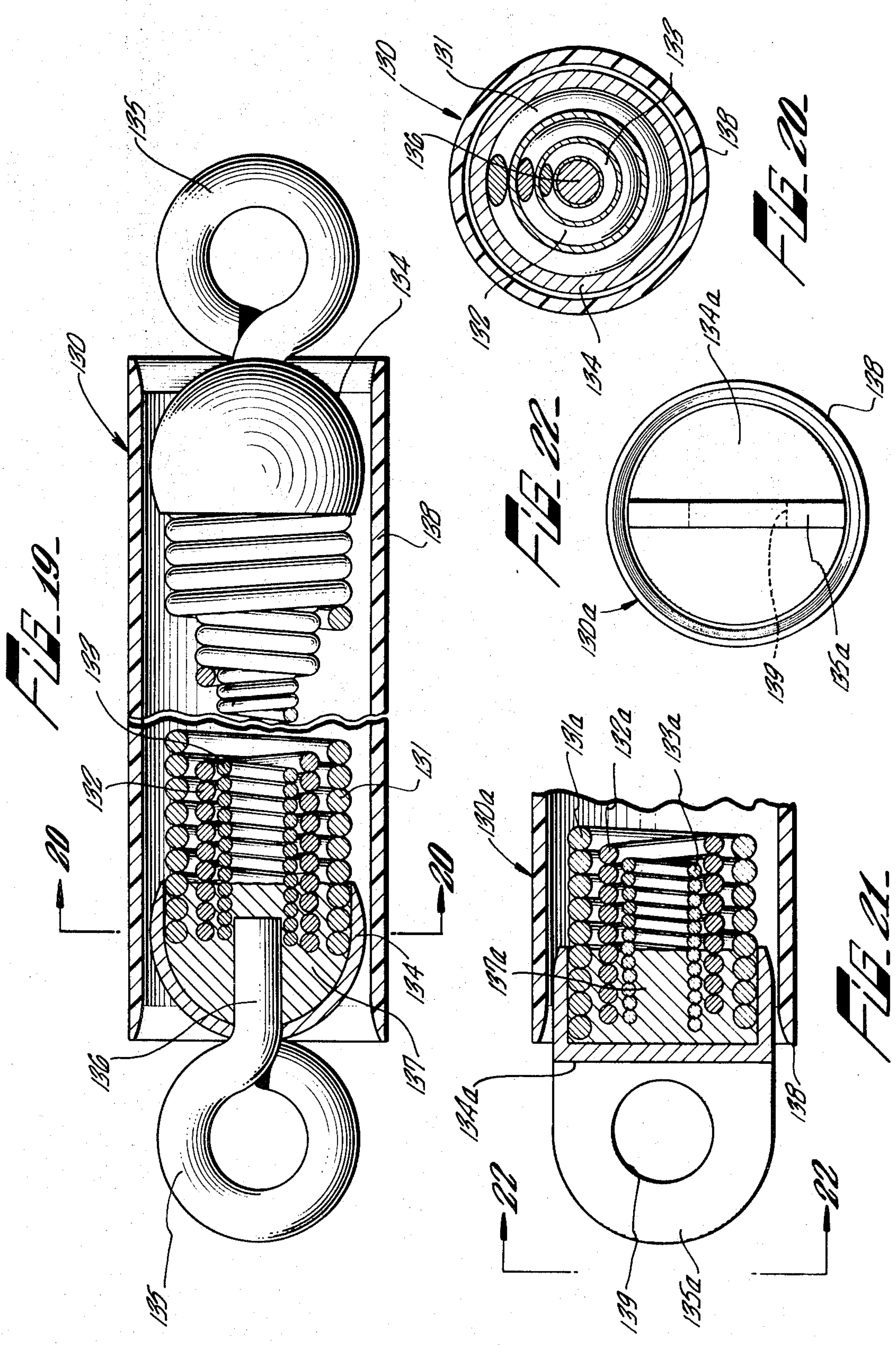

United States Patent Office 3,618,214
Patented Nov. 9, 1971

3,618,214

COILED WIRE SPRING APPLIANCES FOR USE IN ORTHODONTICS

Maclay M. Armstrong, 1306 N. 175th, Suite 106, Seattle, Wash. 98133

Continuation of application Ser. No. 634,029, Apr. 17, 1967, which is a continuation-in-part of application Ser. No. 504,679, Oct. 24, 1965, and a continuation of application Ser. No. 835,882, June 9, 1969, all now abandoned. This application May 4, 1970, Ser. No. 33,151
Int. Cl. A61c 7/00
U.S. Cl. 32—14 A 31 Claims

ABSTRACT OF THE DISCLOSURE

An orthodontic spring applicance to replace rubber or latex elastic bands for application of corrective intermaxillary forces to teeth. The appliance includes several coaxial coil springs secured together at their ends and having a protective flexible sheath therearound. A pair of eyelets are secured at opposite ends of the assembly for engagement with hooks on orthodontic arch wires, brackets, etc. One or more of the coaxial springs may be wound with initial tension, or may be wound as a compression spring to regulate the force delivered by the assembly upon elongation.

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of my copending application Ser. No. 634,029, filed Apr. 17, 1967 and now abandoned, which is in turn a continuation-in-part of my application Ser. No. 504,679, filed Oct. 24, 1965, now abandoned and a streamlined continuation of 835,882, filed June 9, 1969 and now abandoned.

BACKGROUND OF THE INVENTION

This invention relates to orthodontic appliances and their use in practice of orthodontics and more particularly to premanufacture and subsequent installation of coiled-wire spring appliances to correct malocclusions of teeth and/or jaws.

The invention has a broad purpose of providing several embodiments of appliances of one or more coiled wires, both protected and unprotected, for use throughout small working-length distances in limited-space vestibules of the mouth to provide continuous, predictable corrective forces.

Also the invention has a major purpose of providing several embodiments of protected appliances of one or more coiled wires for use in treatment of malrelationships between teeth of opposing jaws. Such protected coiled wires provide known corrective forces which increase upon elongation of the appliance. During normal relative movements of the upper and lower jaws, the coiled wires stay within their elastic limits and remain clear of or protected from mastication.

In providing these embodiments of coiled-wire orthodontic appliances, the practice of orthodontics is further advanced because the sciences of biology and physics are more readily and concisely associated. The resulting biophysics approach to the care of individual patients, by comparison of results in applying known forces for known periods of time, substantially increases the effectiveness of an orthodontist in correcting malocclusions.

This is especially true when these protected coiled wires are used in lieu of rubber or latex strand elastics which previously have been relied on to create forces for correcting malrelationships of opposing arches in orthodontics. As noted by Joseph R. Jarabak and James A. Fizzell

in their book "Technique and Treatment with Light-Wire Appliances," conventional strand elastics have certain advantages. The authors state that strand elastics "can be inserted and removed by the patient. . .. They do not have to be cleaned because they can be thrown away after use . . .. They do not have to be reactivated by the orthodontist." Also, "because they can be removed before eating, they can be used in locations within the mouth where they might otherwise interfere with mastication."

As further discussed by these authors, however, a "principal disadvantage" of strand elastics is the "opportunity for the patient to avoid using the elastics. This can have an important effect on the attainment of the treatment objectives, for elastics often are expected to cooperate with certain other active elements in the treatment of a given case. When the elastics are not being used by the patient, the other active elements continue to work but in a different manner from that which the orthodontist intended. Sometimes the elastics are the principal active elements. In such cases the successful moving of the teeth depends on having almost continuous forces maintained by the elastics. Neglect of the patient to wear his elastics seriously retards progress of treatment." A serious problem with strand elastics is thus the reliance which the orthodontist must place on the patient's cooperation in wearing elastics. Poor cooperation from the patient can defeat achievement of the goals of an otherwise well-planned treatment program.

Another major disadvantage of strand elastics is that the restoring force exerted by the elastic when stretched to a specific elongation is not constant. Fluids in the patient's mouth rapidly affect the physical properties of conventional strand elastics, and a force reduction of about 40% is common after the elastics have been in place for several hours. Even when the patient cooperates by conscientiously wearing the elastics, the orthodontist is thus still unable to apply a controlled, predictable, relatively constant force to malpositioned teeth because the elasticity of the force-delivering device is rapidly decreasing during use.

Therefore, this invention provides protected coiled-wire appliances which are manufactured and used to serve the major functions of orthodontic strand elastics and, moreover, whether protected or not, to serve substantially all inter-arch functions and some intra-arch function of orthodontic force-creating appliances. With special reference to coiled-wire appliances to serve in lieu of strand elastics, they are protected by coatings such as nontoxic rubbers and plastic, and preferably by encompassing tubing made, for example, from a polytetrafluoroethylene plastic material as sold under the trademark "Teflon."

Such tubing-encompassed coiled-wire appliances make superior substitutes for elastics, especially when very-small-diameter wires are coiled and arranged concentrically and/or fitted together. Depending on a hooking or integal-attaching system used by an orthodontist in end mounting of such protected appliances, a patient may or may not be able to remove these appliances. In most treatment plans, the patient will not be able to remove his coiled-wire appliances. They are selected to remain activated continuously throughout each twenty-four hour day and to stay within their elastic limits. Possibly in substituting for strand elastics, their removable capability may be accomplished to avoid interference with mastication during mealtimes. However, as indicated in the drawings, interference with normal chewing can be avoided by proper installation of the coiled-wire appliances.

Because nonremovability of the coiled-wire appliances by the patient will usually be preferred by the orthodontist, and because such appliances are pre-designed to remain within elastic limits, continuous application of known corrective forces is thereby made possible. Such continued force application increases the overall effectiveness and efficiency of orthodontic treatment, resulting in substantial shortening of the duration of the treatment period as well as appointment and service times on the part of the orthodontist, his assistants and his patient. In addition to cost savings directly associated with time savings, there are also comparative cost savings associated with the use of fewer orthodontic materials during these shorter treatment periods.

SUMMARY OF THE INVENTION

The orthodontic appliance of this invention is used to apply force to a malpositioned tooth or teeth in a patient's mouth, and is adapted for engagement between a pair of anchor points such as wire hooks secured to arch wires, orthodontic brackets or tubes, headgear members, and the like. The appliance includes a resilient element such as a helically coiled wire spring which produces a stable and predictable restoring force upon elongation, the element having the property that its restoring force is substantially unaffected by long-term exposure to fluids in the mouth. A pair of fasteners such as eyelets are secured at opposite ends of the resilient element, and are adapted to engage the hooks or other anchor means. Preferably, a protective sheath is disposed around the resilient element, and the appliance preferably further includes a laterally resilient stiffening means (such as a second coil spring) disposed inside the resilient element to give the appliance "body" and strength to resist deformation from side forces as may be imposed during chewing.

In a presently preferred form of the invention, the appliance includes three coil springs of unequal diameter, the springs being telescoped together and secured to each other at opposite respective ends, the appliance further including a protective plastic sheath or tube therearound and an eyelet or other fastener is secured at each of the opposite ends of the appliance for engagement with the wire hooks or other anchor means. Preferably at least one of the springs is wound with initial tension to insure delivery of a substantial orthodontic corrective force at small elongations of the appliances. Where very light corrective forces are desired, one or two of the telescoped springs may be wound as open-coil springs prior to assembly in the appliance. The remaining spring or springs are in closed-coil form with initial tension sufficient to compress the initially open-coil springs into closed-coil form when the springs are assembled together.

BRIEF DESCRIPTION OF THE DRAWINGS

Further understanding of this invention in its many embodiments will be enhanced by reading the following description in which references are made to selected embodiments of the invention as shown in the drawings, wherein:

FIG. 1 is a view looking into opened jaws and teeth which are undergoing Class II type mechanics in orthodontics, as an embodiment of a protected, tensioned coiled-wire appliance creates linearly changing forces;

FIG. 2 is a side view of opened jaws and teeth which are also undergoing Class II type mechanics in orthodontics, as a second embodiment having parallel protected, tensioned coiled-wire appliances creates additive forces upon elongation;

FIG. 3 is an enlarged partial sectional view of a coiled-wire appliance protected with plastic tubing and terminated at each end with soldered eyelet hooks for installation as indicated in FIG. 1;

FIG. 4 is an enlarged partial sectional view of one end of another embodiment wherein two different-diameter coils of two different-diameter wires are arranged concentrically and compactly one within the other, are protected with plastic tubing, and are terminated together with soldered eyelet hooks;

FIG. 5 is an enlarged partial sectional view of one end of another embodiment wherein three different-diameter coils of three different-diameter wires are arranged concentrically and compactly one within the other, are protected with plastic tubing, and are terminated together with soldered eyelet hooks;

FIG. 6 is an enlarged partial sectional view of one end of another embodiment wherein two like-diameter coils of like-diameter wire are interwound or "threaded" together, and are covered by a rubber or rubber-like coating;

FIG. 7 is an enlarged partial sectional view of one end of another embodiment wherein two like-diameter coils of like-diameter wire are interwound or "threaded" together, and a smaller-diameter coil of smaller-diameter wire is arranged concentrically within these interwound coils, this assembly of coils being protected with plastic tubing and terminated with soldered eyelet hooks;

FIG. 8 is an enlarged view, partly broken away, of the parallel or double-barreled appliance illustrated in FIG. 2;

FIG. 9 is a side view of an "overjet" of the upper teeth where the upper teeth are all too far forward in relation to the lower teeth, indicating use of the appliance shown in FIG. 3;

FIG. 10 is a partial side view of a portion of the upper jaw of FIG. 9, indicating how an anchoring hook may be adjusted to increase or to decrease the operating length of a coiled-wire appliance (not shown), thereby modifying the overall active force of the appliance to achieve the optimum desired force;

FIG. 11 is a side view of the teeth, indicating various anchoring-hook installations;

FIG. 12 is a partial front view of the upper and lower front teeth, which have not closed together even though the opposing back teeth are clenched in tight contact, indicating use of a coiled-wire appliance and a special guide-anchoring structure to close the upper and lower front teeth together into their proper closed-bite relationship;

FIG. 13 is a partial front view of jaws indicating use of a coiled-wire appliance and a special guide-anchoring structure to align transversely the upper and lower teeth and jaws;

FIG. 14 is a partial side view of an "underjet" of the lower teeth where the lower teeth are all too far forward in relation to the upper teeth, indicating use of the appliance shown in FIG. 3;

FIGS. 15 and 16 are drawings made from X-ray "head films" showing "before" and "after" relationships of a patient's teeth;

FIGS. 17 and 18 are drawings made from X-ray "head films" showing "before" and "after" relationships of another patient's teeth;

FIG. 19 is a side view, partly broken away and in section, of yet another embodiment of an appliance having three concentric coiled wires, and having a plastic tube fitting loosely over the wires and over a pair of end caps which join the coiled wires;

FIG. 20 is a view taken on line **20—20** of FIG. 19;

FIG. 21 is a partial side view of a modified form of the appliance shown in FIG. 19 in which the bell-shaped end caps include an integral eyelet portion; and

FIG. 22 is a view on line **22—22** of FIG. 21.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The embodiments of protected, tubing-enclosed appliances represented in these figures are believed to be those which will find the most extensive use. As indicated previously, however, these and other coiled-wire configurations could be used in some applications without tubing or coating protection.

The desired working forces in the preferred embodiments of this invention are derived from helically coiled wire springs. When the springs are installed, the resulting forces are determined by the characteristics of the unelongated or static springs, and by the extent of spring elongation which is in turn determined by jaw position and by the distance between terminal end hooks which mount the springs on the opposing arches. Selection of wire type and diameter and of coil configuration and diameter is important in the manufacture of all embodiments. Spring-tempered stainless-steel wire stock is currently available having satisfactory strength and elastic properties. Knowing the basic physical properties of a particular wire, the determination of spring parameters such as wire diameter, number of coils and coil diameter is readily made by referring to any of the readily available texts on helical spring design. The design formulaes are well known and for brevity, will not be stated. There are, however, several general considerations which merit attention regarding spring design for the appliances of this invention, and these considerations are discussed below.

To be functional, versatile, comfortable, and protected against breakage or damage, the orthodontic coil-spring appliances of this invention meet the following requirements:

(1) The appliance must have a small outside diameter so it can be accommodated in the limited space available in the vestibules of the mouth.

(2) The appliance must in many applications have a relatively small "working elongation" or working length. The term "working elongation" is defined as the distance, expressed in terms of a percentage of the length of the unelongated appliance, that the appliance must be elongated to provide a selected corrective force. For example, the appliance may have an unelongated length of say one inch. The positioning of the appliance in the patient's mouth may dictate that the desired force be generated when the appliance is elongated one-fourth inch to a new overall length of 1¼ inches. The working elongation of the appliance is thus 25%. I have found that the appliances of this invention can provide substantial corrective forces when elongated as little as 1/16 inch.

(3) The appliance must be available in various lengths to permit use in a variety of positions and to accommodate a wide range of intermaxillary spans in the mouth. Considerable flexibility is available in the determination of appliance length because other parameters such as wire diameter, cross section and material, coil diameter, and the number of springs can be varied to provide an appliance having the desired unelongated or static length and a desired working elongation.

(4) The appliance must have a substantial amount of "reserve elongation." The term "reserve elongation" is defined as the amount of elongation, expressed in terms of percentage of the length of the unelongated appliance, that the appliance may be elongated over and above the working elongation before permanent deformation or "set" of the coil springs occurs. That is, the appliance must be capable of elongations well beyond that providing the desired corrective force to prevent the spring or springs from being stretched beyond their elastic limit during large excursions of the lower jaw as occur during yawning or shouting. If the spring described above having an unelongated length of one inch and a working elongation of 25% has a reserve elongation of 125%, the appliance could be elongated to a total length of 2½ inches before exceeding the elastic limit of the springs and causing permanent deformation or set. That is, the appliance could be elongated 1¼ inches (125% of the unelongated appliance length) beyond the elongation which produces the desired working force before exceeding the elastic limit of the springs. It is vital that the appliance have adequate reserve elongation because orthodontic patients are typically children and cannot be expected to use great care in avoiding large excursions of the lower jaw which elongate the appliance beyond its normal working length.

(5) A wide range of corrective forces should be available for any particular length of the appliance when it is installed on the patient. Appliances according to the invention are readily constructed to provide light intermaxillary forces of several ounces, or to provide heavy intermaxially forces of perhaps 16 ounces or more.

(6) The appliance should be laterally resilient to provide flexibility when side loads are imposed as may occur during chewing of food. At the same time, the appliance must have sufficient "body" or strength to avoid deformation or breakage of the coil springs when the appliance is subjected to side loads.

(7) The appliance should have attachments at each end which permit simple connection to other orthodontic appliances on the teeth, and are yet strong enough to resist deformation or breaking.

(8) The use of a semi-rigid protective plastic tube around the coil springs of the appliance is highly desirable to add to the lateral strength of the appliance, and to prevent distortion or crushing of the coil springs should the appliance become positioned between teeth of the upper and lower jaws during chewing. The use of a smooth plastic tubing tends to ease the appliance out from between occluding teeth, and also serves to protect the patient's cheek tissue from irritation which might otherwise be caused by the opening and closing of the spring coils.

Appliances of this invention have been constructed which meet all of the above goals, and which are highly resistant to damage or breakage from forces arising from chewing, careless brushing of teeth, or negligent handling by the patient.

Referring to FIG. 3, a first embodiment of the invention is shown as a single-spring appliance **40**. The appliance includes a helically wound coil spring **20**, and a pair of wire fasteners or eyelets **26** and **28** are secured to opposite respective ends **22** and **24** of the spring by oval-shaped masses **30** and **32** of silver-solder in which the first few turns at each end of the spring are embedded. Spring **20** is enclosed in a protective plastic sheath or tube **36** formed of a material suitable for use in the mouth such as plastic marketed under the trademark "Teflon." The inside diameter of the tube is selected such that spring **20** may be extended freely without binding on the inner surface of the tube.

Silver-solder mass **30** has a major diameter slightly larger than the inside diameter of the tube, and an end **34** of the tube is stretched over the mass and retained in position thereby. Silver-solder mass **32** has a major diameter slightly smaller than the inside diameter of tube **36** whereby this mass may slide freely within the tube when the spring is elongated. Wire eyelet **28** has a diameter slightly larger than the inside diameter of an end **38** of tube **36** whereby this eyelet cannot be retracted into the inside of tubing. By this arrangement, spring **20** is maintained under slight tension at zero elongation of the appliance, and all "slack" in the spring is removed such that orthodontic corrective forces are available at even very slight elongations of the appliance.

Appliance **40** is shown in FIG. 1 as installed in the mouth of a patient, and the appliance is positioned to apply an intermaxillary force between the teeth of the upper and lower jaws. FIG. 2 is a side view of a similar application, but here a pair of appliances **40** have been connected in parallel to form a two-barrel appliance **42**. This parallel configuration is useful when relatively high orthodontic corrective forces are required, and the desired force cannot be obtained from a single appliance **40**. An anchor means such as an anchor hook **86** as shown in FIG. 10 is soldered or spot welded to a conventional orthodontic arch-wire mounted in the patient's mouth, and is used for mounting appliances **40** or **42** in position. As suggested in FIG. 10, the degree of elongation of the appliance may be regulated by bending hook **86** until a spring elongation providing the desired corrective force is achieved.

In FIG. 9, appliance **40** is secured to extend between the upper and lower jaws to treat an "upper overjet" or Class II malocclusion in which the upper teeth are too far forward in relation to the lower teeth. Coil spring **20** is elongated, as indicated at **10**, to impose the desired corrective force between the upper and lower jaws. As the teeth in the jaws move toward the desired position in which proper occlusion is achieved, proper elongation of appliance **40** is maintained to provide the corrective force by bending hook **86** forwardly or to the right as seen in FIG. 9.

In the correction of some anterior-posterior malrelationships of opposing dental arches, the posterior teeth (such as the molars) may not provide an adequate anchoring structure for the spring appliances because the teeth have not erupted fully or because the orthodontist does not desire to apply force to these teeth. In such cases, conventional arch-wires **100** and **102** as shown in FIG. 11 are extended rearwardly in the mouth and formed into anchor hooks on which the posterior end of appliances **40** can be secured. This arrangement is desirable as it permits the use of a relatively long spring appliance having a large reserve elongation. The use of arch-wire hooks is shown in FIG. 14 where an "underjet" or Class-III malocclusion is being treated.

In FIG. 12, a modified form of appliance **40** is shown in the treatment of an anterior-open-bite malocculsion. The appliance is formed into a curved U shape, and is held in place by ferrules or metal tubes **106** secured at the ends of wire struts **110** and **112** which in turn are secured to and extend below a lower arch-wire **114**. As the jaws are opened, spring **20** in appliance **40** is elongating throughout its U-shaped length. The selection of the spring is made to permit elongation of the spring within its elastic limits while still providing a desired corrective force.

In FIG. 13, another curved form of appliance **40** is shown in use to correct a transverse misalignment of the teeth and jaws. The appliance is anchored at its ends as described above, and is further positioned by a spur or direction-control hook **120** secured to the arch-wire. When so positioned, the appliance is prevented from being trapped between the teeth during chewing, and does not become entangled with food in the mouth.

A significant feature of the invention is the use of multiple coil springs which are concentrically arranged within the appliance. The use of two or three such concentric springs permits the achievement of relatively high corrective forces at modest spring elongations, and also provides a much higher elongation reserve than is available from a single heavy-force spring. Another important advantage of the multiple-spring construction is that the resulting appliance has considerable "body" or lateral strength in resistance to side forces which might otherwise deform or break the appliance.

In FIG. 4, an appliance **50** according to the invention includes an outer coil spring **46** arranged concentrically around an inner coil spring **48**. The ends of the springs are connected by a silver-solder mass **30** in which an eyelet **26** is also positioned just as described above with reference to appliance **40**. Plastic tube **36** surrounds the springs as also described above. Spring **46** is coiled as a right-hand spring, and spring **48** is coiled as a left-hand spring. This opposite coiling prevents individual coils of the two springs from becoming entangled during appliance elongation, and also adds to the lateral strength of the appliance as the two springs do not tend to become interleaved upon the application of side forces.

A triple-spring **52** is shown in FIG. 5, and includes outer and inner springs **54** and **58**, and a middle spring **56** positioned concentrically between the outer and inner springs. Springs **54** and **58** are wound as right-hand springs, and spring **56** is wound as a left-hand spring to provide lateral strength and to avoid meshing of the spring coils as described above. The construction of appliance **52** is otherwise generally similar to the construction of appliance **40** already described.

Another form of the invention as shown in FIG. 6 in which an appliance **60** includes a pair of threaded-together or interwound coil springs **62** and **64** of substantially equal diameter. A close-fitting protective tube **66** or outer coating is formed of rubber or a rubber-like elastomer, and is secured over the silver-solder masses at the ends of the assembly. In this form of the invention, the protective tube expands with the springs and serves to enclose the interior of the appliance.

An appliance **70** as shown in FIG. 7 is somewhat similar to appliance **60**, except that a single outer spring **64** is used, and the outer spring concentrically surrounds a small-diameter inner coil spring **72** which is wound in a direction opposite to the winding of the outer spring. A protective, plastic tube **36** as described above encloses the springs.

In FIG. 8, a 2-barrel appliance **78** is shown. Appliance **78** is generally similar to appliance **42** shown in FIG. 2, but is formed from a pair of dual-spring appliances **50** as illustrated in FIG. 4, the appliances being linked together at one end by a U-shaped connecting wire. The parallel springs of appliance **78** are useful to provide very heavy orthodontic forces which may be needed in some treatment plans.

To illustrate the effectiveness of the appliances of this invention, "before" and "after" drawings taken from head-film X-rays are shown in FIGS. 15–18. FIGS. 15 and 16 illustrate treatment progress of a 16-year-old male patient who showed poor cooperation in the use of conventional strand elastics. The "before" view of FIG. 15 shows the considerable malpositioning of teeth which existed after eleven months of attempted treatment with conventional strand elastics. Appliances **78** as shown in FIG. 8 were thereafter installed in an orientation such as shown in FIG. 2.

The appliances used on this patient included inner springs formed of 0.006 inch diameter wire coiled helically with an inside diameter of 0.022 inch. Each outer spring was formed of 0.007 inch diameter wire helically coiled with an inside diameter of 0.034 inch. The appliances were elongated during installation to provide 12 ounces of continuous force on each side of the dental arches when the patient's jaws were closed. This force increased when the patient's jaws were opened, but stayed well within the elongation reserve of the springs. After twenty days of treatment with these appliances, the patient's teeth had moved into the corrected position shown in FIG. 16.

FIGS. 17 and 18 show "before" and "after" positions of the teeth of a 13-year-old male patient showing an overjet condition. Correction of this discrepancy required the use of different appliances on each side of the mouth because a differential corrective force was needed between the sides of the mouth. An appliance **78** was installed on one side of the dental arch, and provided about eleven to thirteen ounces of corrective force when the jaws were closed. An appliance **50** was installed on the opposite side of the arch, and exerted 6 to 7 ounces of force when the jaws were closed. The corrected position of the teeth after 53 days of treatment is shown in FIG. 18.

A presently preferred form of the invention is shown in FIG. 19 in which an intermaxillary coil-spring appliance **130** includes an outer spring **131**, a middle spring **132**, and an inner spring **133**. The three springs are coaxially arranged and telescoped together, and the middle spring is wound in a direction opposite to the winding direction of the inner and outer springs to provide lateral stiffness and to avoid undesired engagement of the springs as described above.

A pair of bell-shaped end caps **134** are slipped over opposite ends of the outer spring, and cover the last two or three coils at each end of the outer spring. A pair of circularly shaped fasteners or eyelets **135** have shanks **136**. The eyelets are positioned at opposite ends of the appliance with shanks **136** extending through openings in the end caps to be positioned inside the last few turns of each end of the inner spring. The eyelets and end caps are secured to the springs by a silver-solder mass **137**. This connection can also of course be accomplished by any other suitable binding means such as welding, plastic materials (such as epoxies) or any other conventional fastening technique.

A semi-rigid protective outer sheath or tube **138** is formed of a material such as plastic marketed under the trademark "Teflon," and makes a loose fit over the two end caps. The end caps and springs can thus move freely in and out of the tube as the appliance is elongated and relaxed. The semi-rigid protective tube adds to the lateral strength of the appliance, and tends to ease the appliance from between the teeth should it be trapped during chewing of food. The tube also protects the tissue of the patient's cheeks from irritation which might arise from the opening and closing of the coils of the outer spring.

Preferably, tube **138** is color coded to indicate a characteristic of a particular appliance. For example, various colors can be used in tube **138** to designate the force available from appliances at a given working elongation of say 15% to 20%. Alternatively, the tube color can indicate the static length of the appliance. The appliances will be stocked in a variety of lengths and force ranges, and color coding simplifies the selection process in choosing the covert appliance to fit a particular case. This color coding is a considerable convenience to the orthodontist, and does not overly complicate manufacture of the appliance as suitable plastic tubes are readily available in a variety of colors.

Distortion or other damage to the appliance is also avoided by the design of the end caps and eyelets. The eyelets can swing freely on anchoring hooks in the patient's mouth to avoid binding between the appliance and other fixtures on the patient's teeth. Stress concentrations at the ends of the springs are avoided by insuring that the end caps and silver-solder mass enclose the first two or three turns of the coil springs.

The coil diameters of the concentric coaxial coil springs are preferably such that there is only 0.001 to 0.002 inch clearance between the springs. This slight clearance is enough to avoid friction and energy loss between the springs when the appliance is elongated, and still provides adequate lateral strength in the appliance to resist side forces arising from chewing or negligent handling.

A modified form of the appliance just described is shown in FIGS. 21 and 22 in which an appliance **130***a* incorporates an end cap **134***a* having an outwardly extending portion **135***a*. A hole **139** is formed laterally through portion **135***a*, thus providing a fastener or eyelet through which a hook may be engaged to secure the appliance in the mouth. Springs **131***a*, **132***a* and **133***a* are secured in the end cap by a silver-solder mass **137***a* just as already described with reference to appliance **130**. A second end cap **134***a* (not shown) is of course secured at the other end of the spring assembly.

A typical appliance **130** intended to provide a relatively heavy corrective force has an outer spring **131** formed of 0.012 inch diameter wire with an inside coil diameter of 0.064 inch. Middle spring **132** is formed of 0.009 inch diameter wire with an inside coil diameter of 0.044 inch. Inner spring **133** is formed of 0.006 inch diameter wire with an inside coil diameter of 0.030 inch. The outside diameter of the outer coil spring is 0.088 inch and a semi-rigid tube **138** has an inside diameter of about 0.107 inch. The outside diameter of the entire appliance is a little over one-tenth inch, and is thus small enough to be accommodated easily in the vestibules of the mouth.

To insure that a relatively high force is provided at the small elongations of the appliance, the springs are preferably wound with initial tension. That is, the individual coils of each spring are urged against each other in the winding process, and the resulting compression force must be overcome before the coils of the spring begin to open up. Techniques for forming springs with initial tension are well known, and will not be described in detail. It will be clear, however, that initial tension is produced by bending each coil away from its normal plane as it is wound, thus producing a slight twist in the wire which causes the coil to spring back against the adjacent coil.

In the specific spring described above, the three springs are wound with a total initial tension of about four ounces, and have a maximum elongation before permanent deformation of about one hundred and eighty percent. The appliance provides about 12 ounces of corrective force at a working elongation of about 30%, and the springs have a reserve elongation of about 150% over and above this working elongation.

The use of initial tension in the springs provides a large corrective force at a minimum working elongation, and this feature is important when a very short appliance is needed for installation in a short intermaxillary span. The three springs just described provide a force of slightly over two ounces for each 8% of elongation. An elongation of about 32% thus provides eight ounces of force plus the four ounces of initial tension for a total force of about twelve ounces. Care is taken in designing the appliance to insure that the wire diameter of each spring is so varied in combination with each coil diameter that all three springs have approximately equal, but no more than the necessary maximum elongation. This permits the use of maximum wire diameters in each coil spring, and insures delivery of a heavy force where needed.

Appliance **130** is also useful to provide medium corrective forces in the range of say four to eight ounces. A typical light-force appliance has an outer spring formed of 0.011 inch diameter wire with an inside coil diameter of 0.066 inch. The outer spring is wound with initial tension. The middle spring is formed of 0.009 inch diameter wire with an inside coil diameter of 0.047 inch, and this spring is close wound without initial tension. The inner coil spring is formed of 0.006 inch diameter wire with an inside coil diameter of 0.034 inch. The inner spring is wound with maximum initial tension. The springs are readily designed to have at least 225% elongation before permanent deformation, providing a more-than-adequate safety factor to resist permanent longitudinal deformation.

In some applications, a light force of say one to four ounces may be desired in an intermaxillary coil spring appliance. Even without initial tension wound into the springs, the appliance just described would exert too high a force (in the range of four to eight ounces) at the minimum efficient elongation. It is of course possible to reduce the restoring force of the springs by using spring wire of smaller diameter. Springs formed of smaller diameter wire have the advantage of great reserve elongation, but in some cases the small-diameter wire may not provide sufficient lateral strength or "body" in the overall appliance to resist deformation from chewing or negligent handling. In such cases, it is possible to construct an appliance in accordance with the invention which uses relatively large-diameter wires and still provides light corrective forces. This result is achieved by providing an appliance in which one or more of the springs act as compression springs when the appliance is in a static or unelongated condition.

For example, appliance **130** is readily adapted to provide light orthodontic forces of say one to four ounces by changing the characteristics of the three springs. Preferably, the outer coil spring is wound from slightly smaller diameter wire than used in the examples discussed above. An outer spring wound from 0.009 inch diameter wire has been found satisfactory, the smaller-diameter wire serving both to reduce the spring force upon elongation and to increase very substantially the permissible elongation before deformation or set from about 180% to about 300%. The outer spring is wound with initial tension.

The middle and inner springs **132** and **133** are formed from say 0.008 inch diameter wire and 0.006 inch diameter wire respectively. However, to suit appliance **130** for the delivery of very light orthodontic forces, these springs are wound in the form of open-coil compression springs. That is, the coils of these springs do not touch each other when the springs are "at rest" without any applied force and prior to assembly in the appliance. A light compressive force is thus necessary to bring the coils of these springs together.

The appliance is assembled as described above, and the initial tension of the outer spring is sufficient to compress the middle and inner springs into closed-coil form. That is, when the appliance is "at rest" prior to installation in the mouth, all three springs are in closed-coil form, the initial tension of the outer spring being sufficient to compress the open-coil middle and inner springs.

Another way to make a light-force appliance of this type is to assemble three closed-coil springs in the same manner as already described, but to provide one spring (say the outer spring) with greater reserve elongation than the remaining springs. For example, the outer spring can be capable of 300% elongation before deformation, and the middle and/or inner springs can have a reserve elongation of about 180%. If the assembled appliance is then overelongated to say 225% elongation, the middle and/or inner springs will be overstressed and stretched into open-coil compression-spring form.

When the elongating force is released, the outer spring has sufficient initial tension to buck or overcome the force of the compression springs, and all the springs will be in closed-coil form when the appliance is static or unelongated. The middle and/or inner springs, however, are compressed in this static condition, and are restrained from elongating the static appliance by the initial tension wound into the outer spring. The initial tension of the outer spring is unaffected by the 225% elongation which overstresses the other springs because this spring has a greater reserve elongation of say 300% and this does not reach its yield point.

Whether fabricated by the overstressing technique just described or by assembling combinations of closed-coil and initially open-coil springs, the appliance is readily designed to provide the desired very light orthodontic force at a working elongation of say 15% to 20%. At this working elongation, the middle and inner springs are designed to be relaxed into their original open-coil form, and these springs therefore make no contribution to the overall force delivered by the appliance. That is, at the working elongation, the very light orthodontic force of say one or two ounces is derived solely from extension of the initially tensioned outer spring. The middle and inner springs, however, continue to serve the important function of supporting each other and providing "body" or lateral strength to the appliance, and the outer spring is thereby protected against deformation or crushing which might otherwise ocur during chewing or from negligent handling.

When the jaws are opened as in yawning or shouting, the appliance (as used in intermaxillary applications) will be lengthened beyond its normal working elongation. The middle and inner springs then become conventional extension springs, and act cumulatively with the outer spring. This form of the appliance thus has the characteristic of providing low orthodontic forces at a working elongation of say 15% to 20%, and a considerably increased spring rate over the elongation-reserve range.

Many variations are of course possible in the specific presently preferred form of the invention described above. A spring-tempered wire of noncircular cross section may be used to provide a desired spring rate. The appliance can also be constructed with a single coil spring and a laterally resilient member inside the spring to provide the desired "body" or lateral strength to the appliance. For example, a pair of wires or laterally resilient telescoped tubes can be mounted inside the spring and coupled to

opposite ends of the appliance to slide over each other as the appliance is elongated. The multiple-spring form of the appliance is presently preferred, however, as the several springs support each other to provide good resistance to lateral deforming forces, and the appliance continues to provide a corrective force even if one of the several springs should break or otherwise fail.

The appliances of this invention are also useful as intramaxillary appliances, but are less likely to find widespread use in such applications as the very important elongation-reserve feature of the appliance is normally not needed in an intramaxillary connection.

There has been described a versatile spring appliance which permits an orthodontist to apply a selected and continuous intermaxillary force. The coil springs used in the appliance can be manufactured by conventional techniques to a high degree of precision, thus assuring the delivery of a predictable, continuous force at any specific elongation. The appliances are installed by the orthodontist, and reliance on patient cooperation in wearing conventional strand elastics is eliminated. Corrective forces can be provided at relatively small working elongations, and the amount of tooth movement is thereby automatically limited in the event the patient should fail to keep an appointment and not be seen by the orthodontist for an extended period. Conversely, corrective forces can be provided at relatively large working elongations to permit long intervals between appointments and adjustments, and to permit major tooth movement without the necessity for frequent replacement of the force-supplying appliance.

I claim:

1. An intraoral intermaxillary orthodontic appliance for applying a repositioning force between a pair of teeth in opposite dental arches of a patient's mouth, the appliance comprising:

- a resilient element which produces a stable and predictable restoring force upon elongation, the element being constructed of a material having the property that the amount of restoring force for any given elongation is substantially unaffected by long-term exposure of the element to the environment of the mouth;
- a laterally resilient stiffening means disposed adjacent the resilient element for strengthening the appliance against deformation by lateral forces experienced during mastication and other jaw movement;
- a pair of fasteners secured at opposite ends of the resilient element and adapted to couple the element to the teeth; and
- a sheath disposed around the resilient element;

the resilient element and surrounding sheath being configured to fit within the mouth between the teeth to which the appliance is to be coupled.

2. The orthodontic appliance defined in claim **1** in which the resilient element is a coil spring.

3. The orthodontic appliance defined in claim **2** in which the fasteners are formed as wire eyelets.

4. The orthodontic appliance defined in claim **2** in which the sheath fits loosely over the spring whereby the spring can be elongated within the sheath without corresponding elongation of the sheath.

5. The orthodontic appliance defined in claim **2** in which the stiffening means is a second coil spring disposed within the spring forming the resilient element.

6. An intraoral orthodontic appliance for applying a repositioning force between a pair of anchor points on teeth in a patient's mouth, comprising:

- a coil-spring assembly having a plurality of coaxial coil springs of different diameters, the springs being telescoped together, each spring having first and second ends, the first ends being secured together and the second ends being secured together whereby the springs can be elongated as a unit;
- a pair of fasteners secured at opposite ends of the coil-

spring assembly and adapted to couple the assembly to the anchor points; and

a flexible tube disposed around the coil-spring assembly;

the coil-spring assembly and tube being configured to fit within the mouth between the teeth.

7. The orthodontic appliance defined in claim 6 in which the springs are wound from a spring-tempered stainless-steel wire, and the tube is formed from a polytetrafluoroethylene plastic material.

8. The orthodontic appliance defined in claim 6 in which adjacent springs are wound in opopsite directions to avoid interlocking of the springs during elongation.

9. The orthodontic appliance defined in claim 6 in which at least one of the springs is wound with initial tension.

10. The orthodontic appliance defined in claim 6 in which at least one of the springs is a compression spring when in a closed-coil form.

11. An orthodontic-treatment assembly for applying forces between teeth in upper and lower dental arches of a patient's mouth, comprising:

a coil-spring assembly having a plurality of coil springs of different diameters, the springs being telescoped together, each spring having first and second ends, the first ends being secured together and the second ends being secured together whereby the springs can be elongated as a unit;

a flexible tube disposed around the coil-spring assembly;

a pair of fasteners secured at opposite ends of the coil-spring assembly;

first hook means adapted for mounting on a tooth in one of the dental arches, and further adapted to engage one of the fasteners; and

second hook means adapted for mounting on a tooth in the other dental arch to be spaced from the first hook means, and further adapted to engage the other of the fasteners, whereby the coil-spring assembly can be elongated and engaged with the first and second hook means to apply an intermaxillary corrective force to the teeth, the coil-spring assembly having sufficient reserve elongation that jaw movement during normal chewing and yawning does not elongate the springs beyond an elastic limit.

12. The orthodontic-treatment assembly defined in claim 11 in which one of the hook means is adapted to vary the degree of elongation of the coil-spring assembly whereby the amount of force delivered for any set relationship of the dental arches is adjustable.

13. The orthodontic-treatment assembly defined in claim 11 in which adjacent springs are wound in opposite directions to avoid interlocking of the springs during elongation.

14. The orthodontic-treatment assembly defined in claim 11 in which at least one of the springs is wound with initial tension.

15. The orthodontic-treatment assembly defined in claim 11 in which at least one of the springs is a compression spring when in a closed-coil form.

16. The orthodontic-treatment assembly defined in claim 11 in which the spring ends are secured together with silver solder.

17. The orthodontic-treatment assembly defined in claim 11 and further comprising a pair of end caps secured over opposite ends of the coil-spring assembly.

18. The orthodontic-treatment assembly defined in claim 17 in which the end caps have portions extending away from the spring ends, and the fasteners are formed as holes through the extending portions.

19. The orthodontic-treatment assembly defined in claim 11 in which the coil-spring assembly includes three springs, and further comprising a pair of end caps secured over opposite ends of the assembly.

20. The orthodontic-treatment assembly defined in claim 19 in which the three springs are wound with initial tension.

21. The orthodontic-treatment assembly defined in claim 19 in which two of the springs are wound as compression springs when in a closed-coil form, and the third spring is wound as a closed-coil spring with sufficient initial tension to compress the compression springs into substantially closed-coil form when the springs are secured together.

22. The orthodontic-treatment assembly defined in claim 19 in which the springs have diameters selected to provide clearance between the springs when they are telescoped together, the flexible tube fits loosely over the coil-spring assembly, and adjacent springs are wound in opposite directions, whereby the springs elongate freely without binding on each other and without binding on the tube when the appliance is elongated.

23. The orthodontic-treatment assembly defined in claim 22 in which the flexible tube is color coded to designate a characteristic of the coil-spring assembly.

24. An intraoral orthodontic appliance for applying a repositioning force between first and second teeth in a patient's mouth, comprising:

a coil-spring assembly having a plurality of coil springs which are telescoped together, the springs having differing diameters selected to provide clearance therebetween so the springs can be elongated without binding on each other, each spring having first and second ends, the first ends being secured together and the second ends being secured together whereby the springs can be elongated as a unit;

a pair of fasteners secured at opposite ends of the coil-spring assembly;

first hook means adapted for mounting on the first tooth and adapted to engage one of the fasteners; and

second hook means adapted for mounting on the second tooth to be spaced from the first hook means, and adapted to engage the other of the fasteners, whereby the coil-spring assembly can be elongated and engaged with the first and second hook means to apply a corrective force to the teeth;

the coil-spring assembly being configured to fit within the mouth between the teeth, and being free of longitudinally elongated rigid members extending between the fasteners whereby the assembly has lateral resilience.

25. The orthodontic appliance as in claim 24 wherein the springs are wound from a spring-tempered stainless-steel wire.

26. The orthodontic appliance as in claim 24 wherein the springs are wound in opposite directions to avoid interlocking of the springs during elongation.

27. The orthodontic appliance as in claim 24 wherein at least one of the springs is wound with initial tension.

28. The orthodontic appliance as in claim 24 wherein at least one of the springs is a compression spring when in a closed-coil form.

29. The orthodontic appliance as in claim 24 where one of said hook means is adapted to vary the degree of elongation of the coil-spring assembly whereby the amount of force delivered for any set relationship of the dental arches is adjustable.

30. The orthodontic appliance as in claim 24 wherein said coil-spring assembly includes three springs.

31. The orthodontic appliance as in claim 30 wherein two of said springs are wound as compression springs when in a closed-coil form, and the third spring is wound as a closed-coil spring with sufficient initial tension to compress the compression springs into substantially closed-coil form when the springs are secured together.

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