ORTHODONTIC TOOTH ADJUSTMENT EXPEDITING SYSTEM

Abstract: An orthodontic tooth adjustment expediting system constituted of: a control circuitry; a power supply; a plurality of lingual electrodes adapted to be juxtaposed with a lingual side of an alveolar bone and associated with a particular one of a plurality of tooth sockets within the alveolar bone; and a plurality of buccal electrodes adapted to be juxtaposed with a buccal side of the alveolar bone and associated with a particular one of the plurality of tooth sockets within the alveolar bone, wherein responsive to the control circuitry and the power supply, a first type current is generated between each of the plurality of lingual electrodes and a lingual electrode associated therewith, or a second type current is generated between each of adjacent ones of the plurality of lingual electrodes and between adjacent ones of the plurality of buccal electrodes, each current controlled separately responsive to the control circuitry.

Fig. 3B
ORTHODONTIC TOOTH ADJUSTMENT EXPEDITING SYSTEM

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. application S/N 14/177,573, filed February 11, 2014 and entitled "Method to enhance orthodontic tooth movement", the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The invention relates generally to the field of orthodontic tooth movement and in particularly to an orthodontic tooth adjustment expediting system and method.

BACKGROUND

[0003] Over the past 25 centuries, orthodontists have been engaged in the process of repositioning teeth from faulty arrangements, or "malocclusions," into healthier and more esthetic arrangements. In order to move teeth, three elements are generally required: 1) force, 2) time and 3) space. The mouth responds to a sustained force placed on a tooth by rearranging, or "remodeling," the alveolar bone around the root of the tooth. Particularly, osteoclasts break down bone in the area where the tooth is being moved in order to create space for the tooth. As a result, the tooth is able to move in the direction of the force applied thereto. Additionally, osteoblasts form new bone tissue in the area where the tooth is being moved from.

[0004] In further detail, FIGs. 1A - IB illustrate a "remodeling" of the alveolar bone. As illustrated in FIG. 1A, a tooth is comprised of a crown 0 and a root 1. The crown is visible in the mouth, while the root is not, because it is encased in soft connective tissue fibrous mesh known as the periodontal ligament (PDL) 3, and PDL 3 is surrounded by alveolar bone 4. Alveolar bone 4 faces PDL 3 on one side, and is covered by gingival and mucosal tissue (gum) 5 on the other. PDL 3, alveolar bone 4 and gum 5 contain living cells which are responsible for the remodeling of all these tissues in response to orthodontic forces. This remodeling process is the mechanism that facilitates orthodontic tooth movement.

[0005] As illustrated in FIG. IB, physical changes result from application of an orthodontic force to crown 0 of the tooth. The mechanical forces and moments are
applied to affect the desired type of tooth movement. Accordingly, a tooth may be extruded, intruded, rotated, tipped, or translated. FIG. IB illustrates a translatory movement which results from a translational force 7 and a rotation 6 of crown 0 around a center of rotation, or fulcrum, located near the apex of root 1. In order to insure a translatory movement, a force couple is created opposite to rotational force 6. This force couple (generated by the interaction between the bracket and the arch wire for braces, and attachments and aligners for aligner devices) creates a moment that moves root 1 along with crown 0 extending the center of rotation from the apex to infinity. Translational force 7 pushes root 1 against alveolar bone 4, opposite to the point of force application, compressing a portion 9 of PDL 3. Likewise, on the side of the tooth where force 7 is being applied, a portion 8 of PDL 3 is being stretched. Root 1 is displaced within the tooth socket of alveolar bone 4, and the PDL 3 responds by widening portion 8 and compressing portion 9. The compressed portion 9 undergoes removal (resorption), while in the stretched portion 8 new layers of bone are deposited on the surface of the old alveolar bone 4. Over time, alveolar bone 4 remodels, allowing the tooth to assume a new position in the place that translational force 7 caused it to move. This remodeling is a direct result of, and consistent with, the compression/resorption and stretching/deposition activity in PDL 3 and juxtaposed alveolar bone 4. When alveolar bone 4 is pressed upon, as occurs when translational force 7 presses on a tooth and PDL 3 compresses, a short-lived electrical spike can be measured across alveolar bone's 4 matrix. This is known as a piezoelectric effect, characterized by the negative side of the potential being detected on the concave side of the flexed bone and the positive side of the potential being detected on the convex side. In addition, the mechanical stress causes movement of tissue fluids. These fluids contain electrical charges that change the cellular electric polarity, stimulating the cells to remodel their surrounding matrices. These stress-generated streaming potentials (SGP) last about 20 - 30 minutes. When the bone is held in a flexed state, the concave side experiences bone deposition and the convex side experiences bone resorption. As long as the bone remains flexed, this process continues over time until the previously flexed bone appears unflexed or straight.

[0006] Over the years, orthodontists have invented devices, generally referred to as "appliances", that allow clinicians to deliver sustained forces to the teeth. Braces, or "orthodontic brackets and arch wires," are the classic appliances that most,
if not all orthodontists use. These forces are applied to the crowns of the teeth, then transferred to the dental roots, and from there to the tissues that surround the roots, consisting of the periodontal ligament, a thin soft tissue sleeve that embraces each root, separating it from the surrounding alveolar bone. On the outside, the alveolar bone is covered by the gum. All these tissues must remodel, in order to enable the orthodontically treated teeth to move to new positions in the jaw. Braces consist of small brackets that are glued, or "bonded," to the crowns of teeth, and a wire is then inserted into slots in the brackets and held into place with a ligature or clip. The brackets do not generate forces themselves, but rather transfer forces to the teeth from the deflected wire, when it is inserted into the slot in the bracket and held in place by the ligature. The wire has a "memory," i.e., a characteristic by which the wire tends to return to its original shape, and in doing so, exerts a force on the bracket that is in turn transmitted to the tooth. Through the application of various types, shapes and sizes of wires, the teeth eventually align themselves into the desired position in the dental arch. The technical term used among orthodontists to describe braces is "comprehensive fixed appliance". The tooth movement is clarified by Wolffs Law, which states, in effect, that bone under mechanical stress is remodeled to accommodate and reduce the stress.

Bone cells are responsive to various physical and chemical agents, amongst them: mechanical force and electricity. When direct current, in the order of 20 µA, is applied to bone, deposition of new bone matrix occurs near the cathode, while destruction of old bone is found near the anode. This feature, as well as the ability of bone cells to respond simultaneously to force and electricity, create a favorable environment for acceleration of the rate of bone remodeling and, consequently, the speed of tooth movement. Due to a synergistic relationship between applied force and applied electricity, when both force and electricity are applied simultaneously less of each are necessary to achieve an optimally enhanced osteogenic response from the bone.

Typical orthodontic appliances must be worn by the patient for extended periods of time, often several years or more, in order to achieve the desired results. The classic orthodontic treatment that requires the continuous application of forces to attain the planned tooth movement is expensive, as it requires frequent modifications of the magnitude and direction of forces applied to different teeth, to
achieve the necessary progress, requiring frequent adjustments by the treating orthodontist. Moreover, wearing the mechanical fixtures known as "braces" creates a considerable discomfort for the patient, and at the same time this condition will cause an aesthetic concern to the patient as the metallic fixtures (Braces) are visible to other people. In addition, the braces promote the accumulation of bacteria and viruses, harmful to the teeth and their surrounding tissues.

[0009] In order to overcome some of the above disadvantages, orthodontic appliances have been developed that can be inserted and removed by the patient, and worn part-time. A myriad of removable appliances have been developed over the years, but the vast majority of them are not "comprehensive" in nature, i.e. the removable appliances address specific movements or malocclusions, and are only used for a certain limited period of time. Treatment with removable appliances is often used in conjunction with braces or other appliances.

[0010] U.S. Patent 4,153,060, issued on May 8, 1979 to Korostoff et al., the entire contents of which are incorporated herein by reference, teaches a method and apparatus for electrically stimulating alveolar bone remodeling and tooth movement in the mouths of humans. A positive electrode is placed on the gum surface adjacent the bone structure which is to be resorbed. A negative electrode is placed on the gum surface adjacent the bone tissue which is to be accreted or built up. A current source is connected, such that a small current flows between the electrodes, which have the effect of stimulating bone growth in a specific direction. In a particular arrangement, the electrodes are placed on the gum surface adjacent a tooth, the positive electrode on the side towards which the tooth should move, and the negative on the side from which the tooth will move. Application of a small current to the electrodes will enhance the repositioning of the tooth in conjunction with normal orthodontic practices. However, Korostoff fails to provide a comprehensive and effective system for reducing orthodontic treatment time. Additionally, the electrodes of Korostoff tend to cause excessive irritation of the gums. Although several decades have passed, the method of Korostoff has not achieved wide use by orthodontists.

[0011] U.S. Patent 4,854,865, issued August 8, 1989 to Beard et al., teaches an improved method of orthodontic electro-osteogenesis using a biocompatible anode in contact with an electrolytic gel between the anode and epithelial gingiva at an area of osteoclastic or osteoblastic activity, and a biocompatible cathode in contact with a
different type of electrolytic gel between the cathode and epithelial gingiva at an area of osteoclastic or osteoblastic activity. Current is then applied across the anode and cathode to stimulate osteogenesis. This method stimulates osteogenesis, which is an important element in tooth movement, but is unable to demonstrate how to achieve desirable results, or to enable to complete orthodontic treatment in a shorter amount of time.

[0012] U.S. patent application publication US 2014/0023983, published January 23, 2014 to Lowe et al., the entire contents of which is incorporated herein by reference, is addressed to an electro-orthodontic appliance which helps accelerate orthodontic tooth movement through the application of a controlled electric current to gum and teeth, thus stimulating osteogenesis. Lowe does not provide a comprehensive solution for enhancing orthodontic tooth movement in a plurality of treatment situations, including a combination of bodily and tipping movements of a plurality of teeth. Additionally, the system of Lowe evokes root resorption due to stimulation of cells residing on the surface of the dental root, which is undesirable.

[0013] U.S. patent application publication US 2009/0117513, published May 7, 2009 to Nemeh et al., the entire contents of which is incorporated herein by reference, is addressed to a method and apparatus for concurrent treatment of multiple oral diseases and defects while promoting general oral hygiene utilizing direct current electricity applied to the gingival tissues of the mouth. Nemeh does not provide a system or method of utilizing this electricity for improvement of orthodontic treatment. It is therefore an object of the present disclosure to overcome at least part of the disadvantages of the prior art.

SUMMARY OF THE INVENTION

[0014] Accordingly, it is a principal object of the present invention to overcome disadvantages of prior art methods and arrangements of orthodontic tooth movement. In one embodiment, the is provided by an orthodontic tooth adjustment expediting system comprising: a control circuitry; a power supply; a plurality of lingual electrodes, each of the plurality of lingual electrodes adapted to be juxtaposed with a lingual side of an alveolar bone and associated with a particular one of a plurality of tooth sockets within the alveolar bone; and a plurality of buccal electrodes, each of the plurality of electrodes adapted to be juxtaposed with a buccal side of the alveolar bone and associated with a particular one of the plurality of tooth
sockets within the alveolar bone, wherein, responsive to the control circuitry and the power supply, a first type current is generated between each of the plurality of lingual electrodes and a particular one of the plurality of buccal electrodes, or a second type current is generated between each of adjacent ones of the plurality of lingual electrodes and between adjacent ones of the plurality of buccal electrodes, and wherein each of the generated first type currents, or each of the generated second type currents, is controlled separately responsive to the control circuitry.

[0015] In one embodiment, the direction of each of the generated first type currents, or the direction of each of the generated second type currents, is arranged to expedite bone resorption or deposition caused responsive to an orthodontic force applied to a tooth disposed within the respective tooth socket. In one further embodiment, the system further comprises a first orthodontic appliance arranged to apply the orthodontic force to each of a plurality of teeth disposed within the plurality of tooth sockets. In another embodiment, responsive to the control circuitry and the power supply, a plurality of the first type currents and a plurality of the second type currents are generated.

[0016] In one embodiment, the system further comprises: a lingual member arranged to fit the contour of the gum over the lingual side of the alveolar bone, the plurality of lingual electrodes disposed on the lingual member; and a buccal member arranged to fit the contour of the gum over the buccal side of the alveolar bone, the plurality of buccal electrodes disposed on the buccal member. In another embodiment, the system further comprises a plurality of electrical paths isolated from each other, the control circuitry in electrical communication with each of the plurality of lingual electrodes, or with each of the plurality of buccal electrodes, via a respective one of the plurality of electrical paths.

[0017] In one embodiment, the control circuitry comprises a user input module arranged to receive a current polarity selection user input, wherein responsive to a particular current polarity selection user input received at the user input module, the direction of the generated first type current between a first of the plurality of lingual electrodes and a first of the plurality of buccal electrodes opposes the direction of the generated first type current between a second of the plurality of lingual electrodes and a second of the plurality of buccal electrodes, or the direction of the generated second type current between a pair of adjacent ones of the plurality of lingual electrodes opposes the direction of the generated second type current between
a pair of adjacent ones of the plurality of buccal electrodes, associated with the adjacent ones of the plurality of lingual electrodes. In another embodiment, the control circuitry comprises a user input module arranged to receive an electrode selection user input, wherein responsive to a particular electrode selection user input received at the user input module, a first type current is generated between a first of the plurality of lingual electrodes and a first of the plurality of buccal electrodes, and a first type current is not generated between a second of the plurality of lingual electrodes and a second of the plurality of buccal electrodes, or a second type current is generated between a first pair of adjacent ones of the plurality of lingual electrodes and between a first pair of adjacent ones of the plurality of buccal electrodes, and between a second pair of adjacent ones of the plurality of lingual electrodes and between a second pair of adjacent ones of the plurality of buccal electrodes.

[0018] In one embodiment, a third of the plurality of lingual electrodes is adapted to be juxtaposed with a first side of a particular tooth socket, and a fourth of the plurality of lingual electrodes is adapted to be juxtaposed with a second side of the particular tooth socket, the second side of the tooth socket opposing the first side of the tooth socket, wherein a third of the plurality of buccal electrodes, associated with the third of the plurality of lingual electrodes, is adapted to be juxtaposed with the first side of the particular tooth socket, and a fourth of the plurality of buccal electrodes, associated with the fourth of the plurality of lingual electrodes, is adapted to be juxtaposed with the second side of the particular tooth socket, and wherein the direction of the first type current generated between the third of the plurality of lingual electrodes and the third of the plurality of buccal electrodes opposes the direction of the first type current generated between the fourth of the plurality of lingual electrodes and the fourth of the plurality of buccal electrodes, or the direction of the second type current generated between the third and fourth of the lingual electrodes opposes the direction of the second type current generated between the third and fourth buccal electrodes. In one further embodiment, the system further comprises a second orthodontic appliance arranged to provide a rotation force to a tooth having a root within the particular tooth socket, the rotational orthodontic force arranged to generate rotational motion of the tooth, the generated rotation motion defining: a first motion vector in a first direction at a portion of a first side of the tooth; and a second motion vector, in a second direction opposing the first
direction, at a portion of a second side of the tooth, the second side of the tooth opposing the first side of the tooth; wherein a first axis extending between the third of the plurality of lingual electrodes and the third of the plurality of buccal electrodes is parallel and aligned with the first motion vector, or a second axis extending between the third and fourth of the plurality of lingual electrodes is parallel and aligned with the first motion vector, wherein a third axis extending between the fourth of the plurality of lingual electrodes and the fourth of the plurality of buccal electrodes is parallel and aligned with the second motion vector, or a fourth axis extending between the third and fourth of the plurality of buccal electrodes is parallel and aligned with the second motion vector, and wherein the direction of the first type current generated between the third of the plurality of lingual electrodes and the third of the plurality of buccal electrodes and the direction of the first type current generated between the fourth of the plurality of lingual electrodes and the fourth of the plurality of buccal electrodes are arranged to expedite bone resorption and deposition caused responsive to the provided rotational orthodontic force, or the direction of the second type current generated between the third and fourth lingual electrodes and the direction of the second type current generated between the third and fourth buccal electrodes are arranged to expedite bone resorption and deposition caused responsive to the provided rotation orthodontic force.

[0019] In another embodiment, for each of the generated first or second type currents, the control circuitry is arranged such that the generated first or second type current is alternately provided for a predetermined active duration and not provided for a predetermined quiescent duration, the predetermined active duration being 3 - 5 hours.

[0020] In one embodiment, the system further comprises a plurality of adjustable pressure elements, each of the adjustable pressure elements arranged to apply an adjustable amount of pressure to a respective one of the plurality of lingual electrodes and the plurality of buccal electrodes. In one further embodiment, each of the adjustable pressure elements is arranged to expand responsive to air being injected therewithin, the adjustable amount of pressure applied responsive to the injected air. In another further embodiment, each of the adjustable pressure elements is arranged to expand responsive to a pressure member being inserted therewithin, the adjustable amount of pressure applied responsive to the inserted pressure member.
In one embodiment, the system further comprises: a temperature sensor arranged to sense the temperature of the gums of the alveolar bone; and a heating element arranged to heat the gums of the alveolar bone, responsive to the sensed temperature. In another embodiment, the system further comprises a pH sensor arranged to sense the pH level of the gums of the alveolar bone, wherein the magnitude of the first type currents or the second type currents are adjusted responsive to the sense pH level.

In one independent embodiment, a method of expediting orthodontic tooth adjustment is provided, the method comprising: generating a first type current between each of a plurality of lingual electrodes and a particular one of a plurality of buccal electrodes, or a second type current between each of adjacent ones of the plurality of lingual electrodes and between adjacent ones of a plurality of buccal electrodes, each of the plurality of lingual electrodes adapted to be juxtaposed with a lingual side of an alveolar bone and associated with a particular one of a plurality of tooth sockets within the alveolar bone and each of the plurality of buccal electrodes adapted to be juxtaposed with a buccal side of the alveolar bone and associated with a particular one of the plurality of tooth sockets within the alveolar bone, wherein each of the generated first type currents, or each of the generated second type currents, is controlled separately responsive to a control circuitry.

In one embodiment, the direction of each of the generated first type currents, or the direction of each of the generated second type currents, is arranged to expedite bone resorption or deposition caused responsive to an orthodontic force applied to a tooth disposed within the respective tooth socket. In one further embodiment, the method further comprises generating the orthodontic force. In another embodiment, a plurality of the first type currents and a plurality of the second type currents are generated.

In one embodiment, the separate controlling by the control circuitry is via a plurality of electrical paths isolated from each other. In another embodiment, the method further comprises receiving a particular current polarity selection user input, wherein responsive to the received particular current polarity selection user, the direction of the generated first type current between a first of the plurality of lingual electrodes and a first of the plurality of buccal electrodes opposes the direction of the generated first type current between a second of the plurality of lingual electrodes and a second of the plurality of buccal electrodes, or the direction of the generated second
type current between adjacent ones of the plurality of lingual electrodes opposes the
direction of the generated second type current between adjacent ones of the plurality
of buccal electrodes, associated with the adjacent ones of the plurality of lingual
electrodes.

[0025] In one embodiment, the method further comprises receiving a
particular electrode selection user input, wherein responsive to the received particular
electrode selection user input, a first type current is generated between a first of the
plurality of lingual electrodes and a first of the plurality of buccal electrodes, and a
first type current is not generated between a second of the plurality of lingual
electrodes and a second of the plurality of buccal electrodes, or a second type current
is generated between a first pair of adjacent ones of the plurality of lingual electrodes
and between a first pair of adjacent ones of the plurality of buccal electrodes, and a
second type current is not generated between a second pair of adjacent ones of the
plurality of lingual electrodes and between a second pair of adjacent ones of the
plurality of buccal electrodes. In another embodiment, a first of the generated first
type currents is associated with a first side of a particular one of the plurality of tooth
sockets and a second of the generated first type currents is associated with a second
side of the particular one of the plurality of tooth sockets, opposing the first side of the
particular one of the plurality of tooth sockets, the direction of the second of the
generated first type currents opposing the direction of the first of the generated first
type currents, or a first of the generated second type currents is associated with a third
side of the particular one of the plurality of tooth sockets and a second of the
generated second type currents is associated with a fourth side of the particular one of
the plurality of tooth sockets, opposing the third side of the particular one of the
plurality of tooth sockets, the direction of the second of the generated second type
currents opposing the direction of the first of the generated second type currents.

[0026] In one further embodiment, the method further comprises providing a
rotational orthodontic force to a tooth having a root within the particular tooth socket,
the rotational orthodontic force arranged to generate rotational motion of the tooth, the
generated rotation motion defining: a first motion vector in a first direction at a
portion of a first side of the tooth, the first of the generated first type currents, or the
first of the generated second type currents, parallel and aligned with the first motion
vector; and a second motion vector, in a second direction opposing the first direction,
at a portion of a second side of the tooth, the second side of the tooth opposing the
first side of the tooth, the second of the generated first type currents, or the second of
the generated second type currents, parallel and aligned with the second motion vector.

[0027] In one embodiment, wherein each of the generated first or second type
currents is alternately provided for a predetermined active duration and not provided
for a predetermined quiescent duration, the predetermined active duration being 3 - 5
hours. In another embodiment, the method further comprises applying an adjustable
amount of pressure to a set of the plurality of lingual electrodes and the plurality of
buccal electrodes.

[0028] In one further embodiment, the method further comprises injecting air
within each of a plurality of adjustable pressure elements, the adjustable amount of
pressure applied responsive to the injected air. In another further embodiment, the
method further comprises inserting a pressure member within each of a plurality of
adjustable pressure elements, the adjustable amount of pressure applied responsive to
the inserted pressure members.

[0029] In one embodiment, the method further comprises: sensing the
temperature of the gums of the alveolar bone; and adjusting the temperature of the
gums responsive to the sensed temperature. In another embodiment, the method
further comprises: sensing the pH level of the gums of the alveolar bone; and
adjusting the magnitude of the generated first type current or second type current
responsive to the sensed pH level.

[0030] Additional features and advantages of the invention will become
apparent from the following drawings and description.

25 BRIEF DESCRIPTION OF THE DRAWINGS

[0031] For a better understanding of the invention and to show how the same
may be carried into effect, reference will now be made, purely by way of example, to
the accompanying drawings in which like numerals designate corresponding elements
or sections throughout.

[0032] With specific reference now to the drawings in detail, it is stressed that
the particulars shown are by way of example and for purposes of illustrative
discussion of the preferred embodiments of the present invention only, and are
presented in the cause of providing what is believed to be the most useful and readily
understood description of the principles and conceptual aspects of the invention. In
this regard, no attempt is made to show structural details of the invention in more
detail than is necessary for a fundamental understanding of the invention, the
description taken with the drawings making apparent to those skilled in the art how
the several forms of the invention may be embodied in practice. In the accompanying
drawings:
[0033] FIGs. 1A - 1B illustrate bone "remodeling" of an alveolar bone
responsive to orthodontic appliance pressure applied to a tooth;
[0034] FIGs. 2A - 2D illustrate various high level views of a first embodiment
of an orthodontic tooth adjustment expediting system, according to certain
embodiments;
[0035] FIGs. 3A - 3D illustrate various high level views of a second
embodiment of an orthodontic tooth adjustment expediting system, according to certain
embodiments;
[0036] FIG. 4 illustrates a high level perspective view of a third embodiment
of an orthodontic tooth adjustment expediting system, according to certain
embodiments;
[0037] FIG. 5 illustrates a perspective view of a fourth embodiment of an
orthodontic tooth adjustment expediting system; and
[0038] FIGs. 6A - 6B illustrate a high level flow chart of a method of
expediting orthodontic tooth adjustment, according to certain embodiments.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS
[0039] Before explaining at least one embodiment of the invention in detail, it
is to be understood that the invention is not limited in its application to the details of
construction and the arrangement of the components set forth in the following
description or illustrated in the drawings. The invention is applicable to other
embodiments or of being practiced or carried out in various ways. Also, it is to be
understood that the phraseology and terminology employed herein is for the purpose
of description and should not be regarded as limiting.
[0040] FIGs. 2A - 2B illustrate various a high level perspective views of an
orthodontic tooth adjustment expediting system 10, according to certain embodiments.
Orthodontic tooth adjustment expediting system 10 comprises: a control circuitry 20;
a power supply 30; a plurality of lingual electrodes 40; and a plurality of buccal
electrodes 50. In one embodiment, power supply 30 is rechargeable. In one further
embodiment, power supply 30 comprises a Nickel-Cadmium rechargeable battery. In another further embodiment, power supply 30 comprises a Lithium rechargeable battery.

[0041] Each lingual electrode 40 is adapted to be juxtaposed with a lingual side 60 of an alveolar bone 70. In one embodiment, as will be described below, plurality of lingual electrodes 40 are disposed on a lingual member (not shown) arranged to fit the contour of the gum 80 over lingual side 60 of alveolar bone 70. Each lingual electrode 40 is associated with a particular one of a plurality of tooth sockets 90 within alveolar bone 70. Particularly, in one illustrated embodiment each lingual electrode 40 is positioned between two adjacent tooth sockets 90, i.e. between two adjacent teeth 100. In another embodiment (not shown), a pair of lingual electrodes 40 are positioned between each pair of adjacent tooth sockets 90, a first of the pair of lingual electrodes 40 in proximity to a first of the pair of adjacent tooth sockets 90 and a second of the pair of lingual electrodes 40 in proximity to a second of the pair of adjacent tooth sockets 90.

[0042] Each buccal electrode 50 is adapted to be juxtaposed with a buccal side 65 of alveolar bone 70. In one embodiment, as will be described below, plurality of buccal electrodes 50 are disposed on a buccal member (not shown) arranged to fit the contour of the gum 80 over buccal side 65 of alveolar bone 70. Each buccal electrode 50 is associated with a particular one of tooth sockets 90. Particularly, in one illustrated embodiment each buccal electrode 50 is positioned between two adjacent tooth sockets 90, i.e. between two adjacent teeth 100. In another embodiment (not shown), a pair of buccal electrodes 50 are positioned between each pair of adjacent tooth sockets 90, a first of the pair of buccal electrodes 50 in proximity to a first of the pair of adjacent tooth sockets 90 and a second of the pair of buccal electrodes 50 in proximity to a second of the pair of adjacent tooth sockets 90.

[0043] In one embodiment, each lingual electrode 40 and buccal electrode 50 is generally longitudinally shaped and extends along an axis generally parallel with a longitudinal axis 105 of each tooth 100. In another embodiment, each lingual electrode 40 and buccal electrode 50 extends from about 1 millimeter apical to the gingival margin to the mucogingival junction of gums 80, further optionally extending 1 - 2 millimeters over the mucosal tissue. In one further embodiment, each lingual electrode 40 and buccal electrode 50 is 5 - 6 millimeters in length.
Power source 30 and control circuitry 20 are coupled to each of plurality of lingual electrodes 40 and plurality of buccal electrodes 50 via a respective one of a plurality of electrical paths 55. Preferably, electrical paths 35 are isolated from each other such that control circuitry 20 is arranged to separately control each lingual electrode 40 and buccal electrode 50, as will be described below. In one embodiment, electrical paths 35 are bundled together within a single isolation material. In one embodiment, each lingual electrode 40 and buccal electrode 50 is arranged to be alternately coupled to a first and a second voltage terminal of power source 30. In such an embodiment, control circuitry 20 is arranged to select for each lingual electrode 40 and buccal electrode 50 to which voltage terminal of power source 30 to be coupled to, as will be described below. In another embodiment, lingual electrodes 40 are each coupled to a first voltage terminal of power source 30 and buccal electrodes 50 are each arranged to be alternately coupled to a second and a third voltage terminal of power source 30, the potential at the second voltage terminal greater than the potential at the first voltage terminal and the potential at the third voltage terminal less than the potential at the first voltage terminal. In such an embodiment, control circuitry 20 is arranged to select for each buccal electrode 50 to which voltage terminal of power source 30 to be coupled to, as will be described below.

In another alternate embodiment, buccal electrodes 50 are each coupled to a first voltage terminal of power source 30 and lingual electrodes 40 are each arranged to be alternately coupled to a second and a third voltage terminal of power source 30, the potential at the second voltage terminal greater than the potential at the first voltage terminal and the potential at the third voltage terminal less than the potential at the first voltage terminal. In such an embodiment, control circuitry 20 is arranged to select for each lingual electrode 40 to which voltage terminal of power source 30 to be coupled to, as will be described below.

Electrical paths 35 connecting control circuitry 20 and power source 30 to buccal electrodes 50 are not shown in FIG. 2B for simplicity.

In operation, an orthodontic appliance, such as braces, is connected to teeth 100 and applies pressure to straighten teeth 100. Each tooth 100 which is not in a correct position, i.e. either crooked or out of line with the remainder of teeth 100, has pressure applied thereto by the orthodontic appliance. The pressure applied by the orthodontic appliance moves each of the respective teeth 100 into the appropriate
position, as described above in relation to FIGs. 1A - IB. Control circuitry 20 is arranged to control power source 30 to generate a current between each lingual electrode 40 and an associated lingual electrode 40 or buccal electrode 50. Particularly, each tooth 100 has associated therewith two lingual electrodes 40 and two buccal electrodes 50, as illustrated in FIG. 2C, an axis 120 passing through a first lingual electrode 40 and a first buccal electrode 50 at a first side of tooth 100 and an axis 130 passing through a second lingual electrode 40 and a second buccal electrode 50 at a second side of tooth 100. Only a single pair of lingual electrodes 40 and buccal electrodes 50 are illustrated in FIG. 2C for simplicity, however this is not meant to be limiting in any way. Additionally, the movement of tooth 100 in FIG. 1C is illustrated as a rotational movement, however this is not meant to be limiting in any way.

[0048] In the event that tooth 100 needs to be moved lingually, i.e. towards the tongue, a first and a second orthogonal current is generated. The term Orthogonal current' as used herein means that the current flows in a direction generally orthogonal to the gum line of alveolar bone 70. Particularly, the first orthogonal current is arranged to flow from the first lingual electrode 40 to the first buccal electrode 50, along axis 120, and the second orthogonal current is arranged to flow from the second lingual electrode 40 to the second buccal electrode 50, along axis 130. Responsive to the forces applied by the orthodontic appliance, bone resorption begins on the lingual side of the respective tooth 100 and bone deposition begins on the buccal side of tooth 100. The first and second generated orthogonal currents aid and expedite bone resorption in the vicinity of each of first lingual electrode 40 and second lingual electrode 40, i.e. at the lingual side of tooth 100, and further aid and expedite bone deposition in the vicinity of each of first buccal electrode 50 and second buccal electrode 50, i.e. at the buccal side of tooth 100. As a result, the bone resorption and deposition caused by the orthodontic appliance is enhanced and expedited by the bone resorption and deposition caused by the generated first and second orthogonal currents, thereby expediting the movement of tooth 100.

[0049] In the event that tooth 100 needs to be moved buccally, i.e. away from the tongue, a third and a fourth orthogonal current are generated. Particularly, the third orthogonal current is arranged to flow from the first buccal electrode 50 to the first lingual electrode 40, along axis 120. The second orthogonal current is arranged to flow from the second buccal electrode 50 to the second lingual electrode 40, along
axis 130. As described above in relation to the generated first and second orthogonal currents, the generated third and fourth orthogonal currents aid and expedite the bone resorption on the lingual side of tooth 100 and the bone deposition of the buccal side of tooth 100.

In the event that tooth 100 needs to be moved along the gum line of alveolar bone 70, a first and second parallel current is generated. The term 'parallel current' as used herein means that the current flows in a direction generally parallel to the gum line of alveolar bone 70 in the vicinity of tooth 100. The first parallel current is arranged to flow from the first lingual electrode 40 to the second lingual electrode 40 and the second parallel current is arranged to flow from the first buccal electrode 50 to the second buccal electrode 50. As described above in relation to the generated orthogonal currents, the generated first and second parallel currents aid and expedite the bone resorption on the side of tooth 100 in the direction that tooth 100 is being moved to and the bone deposition on the side of tooth 100 where tooth 100 is being moved from.

In the event that tooth 100 needs to be rotated, in one embodiment opposing orthogonal currents are generated. Particularly, an orthogonal current flowing in a lingual direction, i.e. towards the tongue, is arranged to flow from the first buccal electrode 50 to the first lingual electrode 40. Additionally, an orthogonal current flowing in a buccal direction, i.e. away from the tongue, is arranged to flow from the second lingual electrode 40 to the second buccal electrode 50. As illustrated in FIG. 2C, a rotation of tooth 100 in a rotational direction 140 can be viewed as movement of a first side 150 of tooth 100 in a buccal direction 160 and movement of a second side 170 of tooth 100, opposing first side 150, in a lingual direction 180. As illustrated, axis 120 extends through first lingual electrode 40 and first buccal electrode 50 and axis 130 extends through second lingual electrode 40 and second buccal electrode 50. Therefore, the orthogonal current flowing from first buccal electrode 50 to first lingual electrode 40 aids and expedites the bone resorption at the buccal end of first side 150 of tooth 100 and the bone deposition at the lingual end of first side 150 of tooth 100. Additionally, the orthogonal current flowing from second lingual electrode 40 to second buccal electrode 50 aids and expedites the bone resorption at the lingual end of second side 170 of tooth 100 and the bone deposition at the buccal end of second side 170 of tooth 100. In another embodiment, opposing parallel current are generate each between the respective pair of lingual electrodes 40
and buccal electrodes 50. In one embodiment, the magnitude of each the above described orthogonal and parallel current is about 20 micro-amperes.

[0052] Providing a lingual electrode 40 and a buccal electrode 50 on each side of tooth 100 thus allows for resorption and deposition simultaneously on both sides of tooth 100. In the event that tooth 100 needs to be tipped, i.e. rotated about any rotation axis extending through the middle of the root of tooth 100, the crown of tooth 100 moves in a first direction while the bottom of the root of tooth 100 moves in an opposing direction. As a result, bone resorption and deposition occurs simultaneously on both sides of the center of rotation. The arrangement of orthodontic tooth adjustment expediting system 10 thus allows for enhancement of tipping motion of a tooth 100.

[0053] Thus, each tooth 100 can be separately treated responsive to the orthodontic appliance, the movement of each tooth 100 expedited responsive to the respectively generated orthogonal and/or parallel currents. Advantageously, orthodontic tooth adjustment expediting system 10 provides a comprehensive system for expediting orthodontic tooth adjustment in any of a plurality of treatment situations, including a combination of bodily and tipping movement of a plurality of teeth 100. Particularly, each of the generated orthogonal currents and parallel current are separately controlled by control circuitry 20. As a result, for each lingual electrode 40 and buccal electrode 50, control circuitry 20 will control whether a parallel current or an orthogonal current will be generated thereat and whether the particular electrode will act as an anode, i.e. outputting the current, or as a cathode, i.e. receiving the current.

[0054] As illustrated in FIG. 2D, control circuitry 20 optionally comprises a user input module 190. User input module 190 is arranged to receive user input, optionally via a connection to an external computer. In one embodiment, user input module 190 is arranged to receive a current polarity selection user input. The directions of the above described generated orthogonal and parallel currents are responsive to the received current polarity selection user input. In another embodiment, user input module 190 is arranged to receive an electrode user input. Control circuitry 20 is arranged to select which lingual electrodes 40 and which buccal electrodes 50 are to be activated for generating and receiving current responsive to the received electrode user input. Particularly, if only several teeth 100 need adjusting, only electrodes associated with those teeth 100 are utilized. In one
embodiment, the magnitude of the generated currents can be adjusted via user input module 190.

[0055] In one embodiment, control circuitry 20 is arranged to generate the respective orthogonal and parallel currents for a predetermined active duration. Following the predetermined active duration, control circuitry 20 is arranged to not generate the respective orthogonal and parallel currents for a predetermined quiescent duration. Optionally, the predetermined active duration is 3 - 5 hours and the predetermined quiescent duration is 19 - 21 hours. Advantageously, generating the respective orthogonal and parallel currents for only a fraction of the day avoids damage to gums 80 from too much electrical stimulation. Clinical research has shown that an active duration of up to 5 hours a day does not cause irritation of gums 80, while an active duration of less than 3 hours a day does not effectively enhance orthodontic tooth movement. In one embodiment, the predetermined active duration and/or the predetermined quiescent duration can be adjusted via user input module 190.

[0056] FIGs. 3A - 3D illustrate various high level perspective views of an orthodontic tooth adjustment expediting system 200. Orthodontic tooth adjustment expediting system 200 is in all respects similar to orthodontic tooth adjustment expediting system 10, described above, with the exception that orthodontic tooth adjustment expediting system 200 further comprises: a lingual member 210; and a buccal member 250. In one embodiment, lingual member 210 and buccal member 250 are a single member. In another embodiment, lingual member 210 and buccal member 250 are each comprised of plastic. In a first orthodontic tooth adjustment expediting system 200, illustrated in FIGs. 3A - 3B, lingual member 210 and buccal member 250 are arranged to fit the upper portion of the mouth. Optionally, first orthodontic tooth adjustment expediting system 200 further comprises a structural support member 290 arranged to provide structural support for lingual member 210. In a second orthodontic tooth adjustment expediting system 200, illustrated in FIGs. 3C - 3D, lingual member 210 and buccal member 250 are arranged to fit the lower portion of the mouth.

[0057] The plurality of lingual electrodes 40 are disposed on lingual member 210 and the plurality of buccal electrodes 50 are disposed on buccal member 250. Lingual member 210 is arranged to fit the contour of gum 80 over lingual side 60 of alveolar bone 70 such that lingual electrodes 40 are positioned between teeth 100 and
buccal member 250 is arranged to fit the contour of gum 80 over buccal side 65 of alveolar bone 70 such that buccal electrodes 50 are positioned between teeth 100, as described above in relation to orthodontic tooth adjustment expediting system 10. Control circuitry 20, power source 30 and electrical paths 35 are disposed on lingual member 210 and buccal member 250. Optionally, power source 30 and electrical paths 35 are sealed within cavities, each between two layers of laminated plastic (not shown), thus being isolated from the oral environment. Advantageously, the isolation from the oral environment keeps the electronics of orthodontic tooth adjustment expediting system 200 protected from the oral environment and keeps the oral environment protected from any toxicity of the electronics of orthodontic tooth adjustment expediting system 200. In one embodiment, the cavities each comprise a vacuum.

[0058] As described above, in one embodiment power supply 30 is rechargeable. In such an embodiment, orthodontic tooth adjustment expediting system 200 is arranged to fit on a rechargeable power source. Optionally, power supply power 30 is arranged to be charged wirelessly via an inductive coil. Additionally, in one embodiment, during orthodontic treatment orthodontic tooth adjustment expediting system 200 is arranged to be placed on a base plate (not shown) and power supply 30 is arranged to inductively receive power from the base plate. As a result, the power stored in power supply 30 won’t be wasted during the orthodontic treatment which may utilize increased amounts of power to adjust treatment parameters via control circuitry 20 and/or to detect appropriate conductivity between associated ones of lingual electrodes 40 and buccal electrodes 50, as will be described below in relation to orthodontic tooth adjustment expediting system 300.

[0059] Preferably, orthodontic tooth adjustment expediting system 200 is arranged to operate in cooperation with any standard orthodontic appliance, including: fixed appliances, such as lingual or buccal braces; and removal aligners, such as the Invisalign clear aligner commercially available from Align Technology Inc. of San Jose, California.

[0060] In one embodiment, orthodontic tooth adjustment expediting system 200 can further be utilized to expedite bone filling of tooth extraction sites. Particularly, when a tooth is extracted and no implant is provided for replacing the extracted tooth, the extraction site is left empty. Preferably, bone growth is desired to fill in the empty extraction site. The currents generated by lingual electrodes 40 and
buccal electrodes 50 will aid in the deposition of bone in the empty extraction site. Particularly, parallel currents are received by each of the lingual electrodes 40 and buccal electrodes 50 associated with the tooth extraction site, the parallel currents received from adjacent lingual electrodes 40 and buccal electrodes 50. As described above, bone deposition occurs at an electrode which receives current. In another embodiment, where an implant is inserted, the current generated by lingual electrodes 40 and buccal electrodes 50 will aid in the formation of bone around the implant. In one embodiment, alveolar bone loss caused by dentures can be reversed responsive to bone deposition caused by generated parallel currents, as described above. In another embodiment, periodontal bone defects can be repaired responsive to bone deposition caused by generated parallel currents, as described above.

[0061] Orthodontic tooth adjustment expediting system 200 thus advantageously provides a comprehensive device, adaptive for a plurality of orthodontic patients. Particularly, as described above, a plurality of parallel and/or orthogonal current can be generated, as required for the particular patient's needs. Additionally, as described above, the currents can be adjusted, and/or new currents may be generated in accordance with the orthodontic treatment process.

[0062] FIG. 4 illustrates a high level perspective open view of an orthodontic tooth adjustment expediting system 300. Orthodontic tooth adjustment expediting system 300 is in all respects similar to orthodontic tooth adjustment expediting system 200 with the exception that orthodontic tooth adjustment expediting system 300 further comprises a plurality of adjustable pressure elements 310. Each adjustable pressure element 310 is juxtaposed with a respective one of lingual electrodes 40 and buccal electrodes 50. In one embodiment, each adjustable pressure element 310 comprises a flexible tubule. During the treatment process, as teeth 100 begin to move into the desired positions, the contact between lingual electrodes 40 and gum 80, and the contact between buccal electrodes 50 and gum 80 may become less optimal due to the movement of teeth 100. In one embodiment, air is pumped into each adjustable pressure element 310 thereby expanding the flexible tubule and applying pressure to the respective lingual electrodes 40 and buccal electrodes 50. Responsive to the applied pressure, the respective lingual electrodes 40 and buccal electrodes 50 are pushed against gum 80, thereby improving the contact therewith. Optionally, as illustrated, adjustable pressure elements 310 are attached to a common air channel 320, air being added to adjustable pressure elements 310 via common air channel 320.
Alternatively, a particular gas may be used instead of air. Optionally, common air channel 320 exhibits a unidirectional opening 330, air being injected into common air channel 320 via unidirectional opening 330. In another embodiment, a solid pressure member is inserted into each adjustable pressure element 310, the flexible tubule thereof expanding responsive to the inserted pressure member and applying pressure to the respective lingual electrodes 40 and buccal electrodes 50. Optionally, a plurality of pressure members are provided, with a range of diameters, each thus providing a different amount of pressure to the respective one of lingual electrodes 40 and buccal electrodes 50.

In the embodiment where the pressure is adjusted by air, adjustable pressure elements 310 and common air channels 320 are enclosed between two layers of laminated plastic (not shown) to keep air from escaping orthodontic tooth adjustment expediting system 300. Additionally, adjustable pressure elements 310 and common air channels 320 are closed to keep air from escaping.

In one embodiment, control circuitry 20 is arranged to measure the conductivity, or impedance, between each pair of lingual electrodes 40 and buccal electrodes 50. Particularly, an orthogonal current is generated between each lingual electrode 40 and the associated buccal electrode 50, responsive to the voltage potentials thereat. Alternately, a parallel current is generated between adjacent lingual electrodes 40 and between adjacent buccal electrodes 50. Control circuitry 20 is arranged to measure the magnitude of the generated current and optionally calculate the resistance, or conductivity, between the electrodes. The amount of pressure applied to each lingual electrode 40 and buccal electrode 50 is adjusted to arrive at the desired predetermined resistance or conductivity.

FIG. 5 illustrates a perspective view of a fourth embodiment of an orthodontic tooth adjustment expediting system 400. Orthodontic tooth adjustment expediting system 400 is in all respects similar to orthodontic tooth adjustment expediting system 10 of FIGs. 2A - 2B, with the addition of a temperature sensor 410, a pH sensor 420 and a plurality of heating elements 430, each in communication with control circuitry 20 (connections not shown). In one embodiment, each heating element 430 comprises an infrared (IR) light emitting diode (LED) 430, and is described herein as such. In one embodiment, each of the plurality of IR LEDs 430 is positioned between a respective pair of lingual electrodes 40 or buccal electrodes 50. Temperature sensor 410 and pH sensor 420 are illustrated as being positioned on gum
80 of lingual side 60 of alveolar bone 70, however this is not meant to be limiting in any way.

[0066] In operation, temperature sensor 410 is arranged to sense the temperature in the vicinity of teeth 100. Additionally, pH sensor 420 is arranged to sense the pH level in the vicinity of teeth 100. Control circuitry 20 is arranged to enable IR LEDs 430 to heat gums 80 responsive to the sensed temperature of temperature sensor 410. Particularly, control circuitry 20 is arranged to analyze the output of temperature sensor 410 and determine an average baseline temperature in the vicinity of teeth 100. IR LEDs 430 are arranged to raise the temperature 1 - 2 degrees above the determined average baseline temperature which will enhance the inflammatory response of gums 80, thereby enhancing the osteogenesis response during movement of teeth 100.

[0067] Control circuitry 20 is further arranged to control power source 30 to adjust the amplitude of the generated currents responsive to the sensed pH level. The generated currents can cause a reduction in the pH level due to an electrolytic effect around lingual electrodes 40 and buccal electrodes 50. In the event that the pH level drops below a predetermined value, the current magnitude is reduced so as to avoid excessive acidity gums 80 which can damage teeth 100.

[0068] FIGs. 6A - 6B illustrate a high level flow chart of a method of expediting orthodontic tooth adjustment. In stage 1000, a first type current is generated between each of a plurality of lingual electrodes and a particular one of a plurality of buccal electrodes, as described above in relation to the generated orthogonal currents. Alternately, or additionally, a second type current is generated between each of adjacent ones of the plurality of lingual electrodes and between adjacent ones of the plurality of buccal electrodes, as described above in relation to the generated parallel currents. Optionally, a plurality of first type currents, each between a particular lingual electrode and a particular buccal electrode, and a plurality of second type currents, each between adjacent lingual electrodes or adjacent buccal electrodes, are generated. As described above, a lingual electrode is positioned between each tooth on the lingual side of the alveolar bone and a buccal electrode is positioned between each tooth on the buccal side of the alveolar bone. Each of the generated first and second type currents is controlled separately by a control circuitry. Optionally, each of the lingual and buccal electrodes is in communication with the control circuitry via a respective one of a plurality of electrical paths, isolated from
the rest of the plurality of electrical paths. As will be described below, the control
circuitry is arranged to control the magnitude and direction of each generated current.

[0069] In optional stage 1010, the direction of each generated current of stage 1000 is arranged so as to expedite bone resorption and/or deposition caused responsive to an orthodontic force applied to a tooth disposed within the respective tooth socket associated with the respective electrodes generating the current. Further optionally, the orthodontic force is generated by an orthodontic appliance.

[0070] In optional stage 1020, a particular current polarity selection user input is received. Responsive to the received current polarity selection user input, the direction of a generated first type current of stage 1000 between a first lingual electrode and a first buccal electrode opposes the direction of a generated first type current between a second lingual electrode and a second buccal electrode. Alternatively, or additionally, responsive to the received current polarity selection user input, the direction of a generated second type current of stage 1000 between adjacent lingual electrodes opposes the direction of a generated second type current between adjacent buccal electrodes. Particularly, the direction of each generated current is selected responsive to a user input, thereby allowing flexibility for a wide range of tooth movements, as described above.

[0071] In optional stage 1030, a particular electrode selection user input is received. Responsive to the received electrode selection user input, a first type current of stage 1000 is generated between a first lingual electrode and a first buccal electrode and another first type current is not generated between a second lingual electrode and a second buccal electrode. Alternatively, or additionally, a second type current of stage 1000 is generated between a first pair of adjacent lingual electrodes and between a first pair of adjacent buccal electrodes, and another second type current is not generated between a second pair of adjacent lingual electrodes and between a second pair of adjacent buccal electrodes. Particularly, the number of generated first and second type currents is selected responsive to a user input.

[0072] In optional stage 1040, a first and a second first type currents, exhibiting opposing directions, are generated. Each of the first type currents, i.e. orthogonal currents, is associated with an opposing side of a tooth socket. Alternatively, or additionally, a first and a second second type currents, exhibiting opposing direction, are generated. Each of the second type currents, i.e. parallel currents, is associated with an opposing side of a tooth socket. In optional stage 1050,
an orthodontic rotational force is provided by an orthodontic appliance, the orthodontic rotational force generating rotational motion of a tooth. The rotational motion defines a first and a second opposing motion vectors at opposing sides of the tooth. The opposing first type currents, or second type currents, of optional stage 1040 are each generally parallel and aligned with a respective one of the motion vectors.

[0073] In optional stage 1060, the generated currents of stage 1000 are alternately provided for a predetermined active duration and not provided for a predetermined quiescent duration. Optionally, the predetermined active duration is 3 - 5 hours and the predetermined quiescent duration is 19 - 21 hours.

[0074] In optional stage 1070, an adjustable amount of pressure is applied to each of the plurality of lingual and buccal electrodes of stage 1000. Optionally, the adjustable amount of pressure is applied responsive to air being injected into a flexible tubule, the tubule expanding responsive to the injected air and applying pressure to an associated electrode. Optionally, the adjustable amount of pressure is applied responsive to a pressure member being inserter into each of the plurality of flexible tubules, the tubule expanding responsive to the inserted pressure member and applying pressure to the associated electrode.

[0075] In optional stage 1080, the temperature of the gums is sensed by a temperature sensor and the temperature of the gums is adjusted responsive to the sensed temperature. In one embodiment, the gums are heated by a plurality of IR LEDs to 1 - 2 degrees above an average baseline temperature of the gums. As described above, heating the gums enhances the inflammatory response of the gums, thereby enhancing the osteogenesis response during movement of the teeth.

[0076] In optional stage 1090, the pH level of the gums is sensed by a pH sensor and the magnitude of the generated first current, or second current, of stage 1000 is adjusted responsive to the sensed pH level. Particularly, in the event that the pH level is below a predetermined value, the magnitude of the current is reduced.

[0077] It is appreciated that certain features of the invention, which are, for clarity, described in the context of separate embodiments, may also be provided in combination in a single embodiment. Conversely, various features of the invention which are, for brevity, described in the context of a single embodiment, may also be provided separately or in any suitable sub-combination.
Unless otherwise defined, all technical and scientific terms used herein have the same meanings as are commonly understood by one of ordinary skill in the art to which this invention belongs. Although methods similar or equivalent to those described herein can be used in the practice or testing of the present invention, suitable methods are described herein.

All publications, patent applications, patents, and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the patent specification, including definitions, will prevail. In addition, the materials, methods, and examples are illustrative only and not intended to be limiting.

The terms "include", "comprise" and "have" and their conjugates as used herein mean "including but not necessarily limited to".

It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather the scope of the present invention is defined by the appended claims and includes both combinations and sub-combinations of the various features described hereinabove as well as variations and modifications thereof, which would occur to persons skilled in the art upon reading the foregoing description.
CLAIMS

1. An orthodontic tooth adjustment expediting system comprising:
   a control circuitry;
   a power supply;
   a plurality of lingual electrodes, each of said plurality of lingual electrodes adapted to be juxtaposed with a lingual side of an alveolar bone and associated with a particular one of a plurality of tooth sockets within the alveolar bone; and
   a plurality of buccal electrodes, each of said plurality of electrodes adapted to be juxtaposed with a buccal side of the alveolar bone and associated with a particular one of the plurality of tooth sockets within the alveolar bone,
   wherein, responsive to said control circuitry and said power supply, a first type current is generated between each of said plurality of lingual electrodes and a particular one of said plurality of buccal electrodes, or a second type current is generated between each of adjacent ones of said plurality of lingual electrodes and between adjacent ones of said plurality of buccal electrodes, and
   wherein each of said generated first type currents, or each of said generated second type currents, is controlled separately responsive to said control circuitry.

2. The system of claim 1, wherein the direction of each of said generated first type currents, or the direction of each of said generated second type currents, is arranged to expedite bone resorption or deposition caused responsive to an orthodontic force applied to a tooth disposed within the respective tooth socket.

3. The system of claim 2, further comprising a first orthodontic appliance arranged to apply the orthodontic force to each of a plurality of teeth disposed within the plurality of tooth sockets.

4. The system of claim 1, wherein responsive to said control circuitry and said power supply, a plurality of said first type currents and a plurality of said second type currents are generated.

5. The system of claim 1, further comprising:
a lingual member arranged to fit the contour of the gum over the lingual side of the alveolar bone, said plurality of lingual electrodes disposed on said lingual member; and

a buccal member arranged to fit the contour of the gum over the buccal side of the alveolar bone, said plurality of buccal electrodes disposed on said buccal member.

6. The system of claim 1, further comprising a plurality of electrical paths isolated from each other, said control circuitry in electrical communication with each of said plurality of lingual electrodes, or with each of said plurality of buccal electrodes, via a respective one of said plurality of electrical paths.

7. The system of claim 1, wherein said control circuitry comprises a user input module arranged to receive a current polarity selection user input,

wherein responsive to a particular current polarity selection user input received at said user input module, the direction of said generated first type current between a first of said plurality of lingual electrodes and a first of said plurality of buccal electrodes opposes the direction of said generated first type current between a second of said plurality of lingual electrodes and a second of said plurality of buccal electrodes,

or the direction of said generated second type current between a pair of adjacent ones of said plurality of lingual electrodes opposes the direction of said generated second type current between a pair of adjacent ones of said plurality of buccal electrodes, associated with said adjacent ones of said plurality of lingual electrodes.

8. The system of claim 1, wherein said control circuitry comprises a user input module arranged to receive an electrode selection user input,

wherein responsive to a particular electrode selection user input received at said user input module, a first type current is generated between a first of said plurality of lingual electrodes and a first of said plurality of buccal electrodes, and a first type current is not generated between a second of said plurality of lingual electrodes and a second of said plurality of buccal electrodes,

or a second type current is generated between a first pair of adjacent ones of said plurality of lingual electrodes and between a first pair of adjacent ones of said
plurality of buccal electrodes, and a second type current is not generated between a second pair of adjacent ones of said plurality of lingual electrodes and between a second pair of adjacent ones of said plurality of buccal electrodes.

9. The system of claim 1, wherein a third of said plurality of lingual electrodes is adapted to be juxtaposed with a first side of a particular tooth socket, and a fourth of said plurality of lingual electrodes is adapted to be juxtaposed with a second side of the particular tooth socket, the second side of the tooth socket opposing the first side of the tooth socket,

wherein a third of said plurality of buccal electrodes, associated with said third of said plurality of lingual electrodes, is adapted to be juxtaposed with the first side of the particular tooth socket, and a fourth of said plurality of buccal electrodes, associated with said fourth of said plurality of lingual electrodes, is adapted to be juxtaposed with the second side of the particular tooth socket, and

wherein the direction of said first type current generated between said third of said plurality of lingual electrodes and said third of said plurality of buccal electrodes opposes the direction of said first type current generated between said fourth of said plurality of lingual electrodes and said fourth of said plurality of buccal electrodes, or the direction of said second type current generated between said third and fourth of said lingual electrodes opposes the direction of said second type current generated between said third and fourth buccal electrodes.

10. The system of claim 9, further comprising a second orthodontic appliance arranged to provide a rotation force to a tooth having a root within the particular tooth socket, said rotational orthodontic force arranged to generate rotational motion of the tooth, said generated rotation motion defining:

a first motion vector in a first direction at a portion of a first side of the tooth; and

a second motion vector, in a second direction opposing said first direction, at a portion of a second side of the tooth, the second side of the tooth opposing the first side of the tooth;

wherein a first axis extending between said third of said plurality of lingual electrodes and said third of said plurality of buccal electrodes is parallel and aligned
with said first motion vector, or a second axis extending between said third and fourth of said plurality of lingual electrodes is parallel and aligned with said first motion vector,

wherein a third axis extending between said fourth of said plurality of lingual electrodes and said fourth of said plurality of buccal electrodes is parallel and aligned with said second motion vector, or a fourth axis extending between said third and fourth of said plurality of buccal electrodes is parallel and aligned with said second motion vector, and

wherein the direction of said first type current generated between said third of said plurality of lingual electrodes and said third of said plurality of buccal electrodes and the direction of said first type current generated between said fourth of said plurality of lingual electrodes and said fourth of said plurality of buccal electrodes are arranged to expedite bone resorption and deposition caused responsive to said provided rotational orthodontic force, or the direction of said second type current generated between said third and fourth lingual electrodes and the direction of said second type current generated between said third and fourth buccal electrodes are arranged to expedite bone resorption and deposition caused responsive to said provided rotation orthodontic force.

11. The system of any of claims 1 - 10, wherein, for each of said generated first or second type currents, said control circuitry is arranged such that said generated first or second type current is alternately provided for a predetermined active duration and not provided for a predetermined quiescent duration, said predetermined active duration being 3 - 5 hours.

12. The system of claim 1, further comprising a plurality of adjustable pressure elements, each of said adjustable pressure elements arranged to apply an adjustable amount of pressure to a respective one of said plurality of lingual electrodes and said plurality of buccal electrodes.

13. The system of claim 12, wherein each of said adjustable pressure elements is arranged to expand responsive to air being injected therewithin, said adjustable amount of pressure applied responsive to said injected air.
14. The system of claim 12, wherein each of said adjustable pressure elements is arranged to expand responsive to a pressure member being inserted therewithin, said adjustable amount of pressure applied responsive to said inserted pressure member.

15. The system of claim 1, further comprising:
   a temperature sensor arranged to sense the temperature of the gums of the alveolar bone; and
   a heating element arranged to heat the gums of the alveolar bone, responsive to said sensed temperature.

16. The system of claim 1, further comprising a pH sensor arranged to sense the pH level of the gums of the alveolar bone,
   wherein the magnitude of said first type currents or said second type currents are adjusted responsive to said sense pH level.

17. A method of expediting orthodontic tooth adjustment, the method comprising:
   generating a first type current between each of a plurality of lingual electrodes and a particular one of a plurality of buccal electrodes, or a second type current between each of adjacent ones of the plurality of lingual electrodes and between adjacent ones of a plurality of buccal electrodes, each of the plurality of lingual electrodes adapted to be juxtaposed with a lingual side of an alveolar bone and associated with a particular one of a plurality of tooth sockets within the alveolar bone and each of the plurality of buccal electrodes adapted to be juxtaposed with a buccal side of the alveolar bone and associated with a particular one of the plurality of tooth sockets within the alveolar bone,
   wherein each of said generated first type currents, or each of said generated second type currents, is controlled separately responsive to a control circuitry.

18. The method of claim 17, wherein the direction of each of said generated first type currents, or the direction of each of said generated second type currents, is arranged to expedite bone resorption or deposition caused responsive to an orthodontic force applied to a tooth disposed within the respective tooth socket.
19. The method of claim 18, further comprising generating said orthodontic force.

20. The method of claim 17, wherein a plurality of said first type currents and a plurality of said second type currents are generated.

21. The method of claim 17, wherein said separate controlling by the control circuitry is via a plurality of electrical paths isolated from each other.

22. The method of claim 17, further comprising receiving a particular current polarity selection user input,

wherein responsive to said received particular current polarity selection user, the direction of said generated first type current between a first of the plurality of lingual electrodes and a first of the plurality of buccal electrodes opposes the direction of said generated first type current between a second of the plurality of lingual electrodes and a second of the plurality of buccal electrodes, or

the direction of said generated second type current between adjacent ones of the plurality of lingual electrodes opposes the direction of said generated second type current between adjacent ones of the plurality of buccal electrodes, associated with said adjacent ones of the plurality of lingual electrodes.

23. The method of claim 17, further comprising receiving a particular electrode selection user input,

wherein responsive to said received particular electrode selection user input, a first type current is generated between a first of the plurality of lingual electrodes and a first of the plurality of buccal electrodes, and a first type current is not generated between a second of the plurality of lingual electrodes and a second of the plurality of buccal electrodes,

or a second type current is generated between a first pair of adjacent ones of the plurality of lingual electrodes and between a first pair of adjacent ones of the plurality of buccal electrodes, and a second type current is not generated between a second pair of adjacent ones of the plurality of lingual electrodes and between a second pair of adjacent ones of the plurality of buccal electrodes.
24. The method of claim 17, wherein a first of said generated first type currents is associated with a first side of a particular one of the plurality of tooth sockets and a second of said generated first type currents is associated with a second side of the particular one of the plurality of tooth sockets, opposing the first side of the particular one of the plurality of tooth sockets, the direction of said second of said generated first type currents opposing the direction of said first of said generated first type currents, or

a first of said generated second type currents is associated with a third side of the particular one of the plurality of tooth sockets and a second of said generated second type currents is associated with a fourth side of the particular one of the plurality of tooth sockets, opposing the third side of the particular one of the plurality of tooth sockets, the direction of said second of said generated second type currents opposing the direction of said first of said generated second type currents.

25. The method of claim 24, further comprising providing a rotational orthodontic force to a tooth having a root within the particular tooth socket, said rotational orthodontic force arranged to generate rotational motion of the tooth, said generated rotation motion defining:

a first motion vector in a first direction at a portion of a first side of the tooth, said first of said generated first type currents, or said first of said generated second type currents, parallel and aligned with said first motion vector; and

a second motion vector, in a second direction opposing said first direction, at a portion of a second side of the tooth, the second side of the tooth opposing the first side of the tooth, said second of said generated first type currents, or said second of said generated second type currents, parallel and aligned with said second motion vector.

26. The method of any of claims 17 - 25, wherein each of said generated first or second type currents is alternately provided for a predetermined active duration and not provided for a predetermined quiescent duration, said predetermined active duration being 3 - 5 hours.
27. The method of claim 17, further comprising applying an adjustable amount of pressure to a set of said plurality of lingual electrodes and said plurality of buccal electrodes.

28. The method of claim 27, further comprising injecting air within each of a plurality of adjustable pressure elements, said adjustable amount of pressure applied responsive to said injected air.

29. The method of claim 27, further comprising inserting a pressure member within each of a plurality of adjustable pressure elements, said adjustable amount of pressure applied responsive to said inserted pressure members.

30. The method of claim 17, further comprising:
   sensing the temperature of the gums of the alveolar bone; and
   adjusting the temperature of the gums responsive to said sensed temperature.

31. The method of claim 17, further comprising:
   sensing the pH level of the gums of the alveolar bone; and
   adjusting the magnitude of said generated first type current or second type current responsive to said sensed pH level.
Fig. 2C

Fig. 2D
GENERATE A FIRST CURRENT BETWEEN EACH OF A PLURALITY OF LINGUAL ELECTRODES AND A PARTICULAR ONE OF A PLURALITY OF BUCCAL ELECTRODES, OR A SECOND CURRENT BETWEEN EACH OF ADJACENT ONES OF THE PLURALITY OF LINGUAL ELECTRODES AND BETWEEN ADJACENT ONES OF A PLURALITY OF BUCCAL ELECTRODES, OPT. PLURALITY OF FIRST CURRENTS AND PLURALITY OF SECOND CURRENTS, EACH CURRENT CONTROLLED SEPARATELY BY CONTROL CIRCUITRY, OPT. VIA ISOLATED PATHS

(OPT.) DIRECTION OF EACH CURRENT ARRANGED TO EXPEDITE BONE RESORPTION OR DEPOSITION CAUSED RESPONSIVE TO AN ORTHODONTIC FORCE APPLIED TO A TOOTH, OPT. GENERATE ORTHODONTIC FORCE

(OPT.) RECEIVE PARTICULAR CURRENT POLARITY SELECTION USER INPUT, DIRECTION OF FIRST CURRENT BETWEEN FIRST LINGUAL AND BUCCAL ELECTRODES OPPOSING DIRECTION OF FIRST CURRENT BETWEEN SECOND LINGUAL AND BUCCAL ELECTRODES, OR DIRECTION OF SECOND CURRENT BETWEEN ADJACENT LINGUAL ELECTRODES OPPOSING DIRECTION OF SECOND CURRENT BETWEEN ADJACENT BUCCAL ELECTRODES

(OPT.) RECEIVE PARTICULAR ELECTRODE SELECTION USER INPUT, A FIRST CURRENT GENERATED BETWEEN A FIRST LINGUAL ELECTRODE AND A FIRST BUCCAL ELECTRODE AND A FIRST CURRENT NOT GENERATED BETWEEN A SECOND LINGUAL ELECTRODE AND A SECOND BUCCAL ELECTRODE, OR A SECOND CURRENT GENERATED BETWEEN A FIRST PAIR OF ADJACENT LINGUAL ELECTRODES AND BETWEEN A FIRST PAIR OF ADJACENT BUCCAL ELECTRODES, AND A SECOND CURRENT NOT GENERATED BETWEEN A SECOND PAIR OF ADJACENT LINGUAL ELECTRODES AND BETWEEN A SECOND PAIR OF ADJACENT BUCCAL ELECTRODES

TO STAGE 1040

Fig. 6A
(OPT.) FIRST AND SECOND GENERATED FIRST CURRENTS, WITH OPPOSING DIRECTIONS, ASSOCIATED WITH OPPOSING SIDES OF TOOTH SOCKET, OR FIRST AND SECOND GENERATED SECOND CURRENTS, WITH OPPOSING DIRECTIONS, ASSOCIATED WITH OPPOSING SIDES OF TOOTH SOCKET

(OPT.) PROVIDE ROTATIONAL FORCE GENERATING ROTATION MOTION DEFINING FIRST AND SECOND OPPOSING MOTION VECTORS AT OPPOSING TOOTH SIDES, FIRST OPPOSING CURRENTS, OR SECOND OPPOSING CURRENTS PARALLEL AND ALIGNED WITH MOTION VECTORS

(OPT.) CURRENTS ALTERNATELY PROVIDED FOR PREDETERMINED ACTIVE DURATION AND NOT PROVIDED FOR A PREDETERMINED QUIESCENT DURATION, OPT. 3 – 5 HOURS

(OPT.) APPLY ADJUSTABLE AMOUNT OF PRESSURE TO RESPECTIVE ELECTRODE, OPT. RESPONSIVE TO AIR INJECTED WITHIN ADJUSTABLE PRESSURE ELEMENT, OPT. RESPONSIVE TO INSERTED PRESSURE MEMBER

(OPT.) MEASURE TEMPERATURE OF GUMS AND ADJUST GUM TEMPERATURE RESPONSIVE THERETO

(OPT.) MEASURE PH OF GUMS AND ADJUST CURRENT RESPONSIVE THERETO

Fig. 6B
**INTERNATIONAL SEARCH REPORT**

International application No
PCT/US2015/015409

A. CLASSIFICATION OF SUBJECT MATTER

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<th>A61N1/05</th>
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According to International Patent Classification (IPC) or to both national classification and IPC.

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

Date of the actual completion of the international search
5 May 2015

Date of mailing of the international search report
13/05/2015

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Kerner, Bodo

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## International Search Report

**International application No**

PCT/US2015/015409

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