Piezosurgery in Surgically Assisted Orthodontic Treatment

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Abstract: Piezosurgery has been applied in dentistry for many years. This paper reviews specifically the treatment applications that have been used in surgically assisted orthodontic treatment since the last decade. Piezosurgery has been applied for surgically-assisted rapid maxillary expansion exposure of palatally impacted canines tooth movement acceleration orthognathic surgery distraction osteogenesis posterior maxillary segmental osteotomy concomitant with sinus lift.

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Introduction

A significant increasing number of adult patients are seeking orthodontic treatment, and a short treatment time is always requested. It is well known that orthodontic treatment time ranges between 1–3 years, depending on the extent of the problem. Treatment efficiency is one of the goals of every practitioner. To improve efficiency, a number of innovative techniques have been developed to minimize treatment duration. Acceleration of orthodontic tooth movement has been extensively reported following a combination of selective alveolar decortication and bone grafting surgery. Corticotomy-assisted orthodontic treatment (Hassan, Al-Fraidi et al. 2010) has been employed in various forms over the past years to speed up orthodontic treatments.

Osseous surgery can be performed by either manual, motor-driven instruments, or ultrasonic devices. Manual instruments offer good control when used to remove small amounts of bone in areas with relatively less dense mineralization. However, manual instruments are difficult to control in order to achieve precise cutting in cortical bone, which is better performed by motor-driven instruments or ultrasonic devices. Motor-driven instruments transform electric or pneumatic energy into mechanical cutting action using the sharpened edge of burs or saw blades. These instruments generate a significant amount of heat in the cutting zone and decrease tactile sensitivity. This is particularly troublesome when cutting across an area of dense cortical bone into either trabecular bone or soft tissue, as when drilling an osteotomy above the mandibular canal or preparing a lateral window for sinus grafting (Seshan, Konuganti et al. 2009). To overcome these drawbacks of manual and motor-driven instruments, ultrasonic devices were introduced in bone surgery for surgically assisted orthodontic treatment (SAOT).

Ultrasound is an oscillating sound pressure wave with a frequency greater than the upper limit of the human hearing range, which is 20 kHz. The range of frequencies employed in the original ultrasonic units was between 25 and 40 kHz. (Stock 1991). Two rudimental ways of ultrasound production are used in dentistry; magnetostriction and piezoelectric manipulation.

A. Magnetostriction

Magnetostriction converts electromagnetic energy into mechanical energy by virtue of vibrations in magnetostrictive metal strips produced via an alternating magnetic field (Plotino, Pameijer et al. 2007). Magnetostriction has tips that move in a figure eight (elliptical) motion, which is less desirable for surgical use.

B. Piezoelectric Surgery

Piezoelectric surgery, also simply known as piezosurgery, is an osseous surgical technique first described by Vercellotti (2004) utilizing an innovative ultrasonic surgical apparatus, known as the Mectron piezosurgery device. Piezosurgery was developed in response to the need to reach major levels of precision and intra-operative safety in bone surgery, as compared to that available by the traditional manual and motorized bone cutting instruments. It is claimed as ideal to perform osteotomies in thin and fragile bones.

The piezosurgery device is basically an ultrasound machine with modulated frequency and a controlled tip vibration range. The ultrasonic frequency is modulated from 10, 30, and 60 cycles/s (Hz) to 29 kHz. The low frequency permits highly precise and safe hard tissue cutting. Nerves, vessels, and soft tissue are not injured by the micro-vibrations, which are optimally adjusted to target only mineralized tissue. The selective and thermally harmless nature of the piezosurgical instruments results in a low bleeding tendency. Power can be adjusted from 2.8 to 16 W, with preset power settings for various types of bone density. The piezosurgery tip vibrates within a range of 60-200 mm, which allows clean cutting with precise incisions (Vercellotti 2004).

The tips of piezoelectric units work in a linear, back-and-forth, "piston-like" motion, which is ideal for surgery. A transition to piezoelectric units offered the advantage of more cycles per second, 40 versus 24 kHz, and less heat generation (Plotino, Pameijer et al. 2007). Light weight and their lack of reliance upon water cooling are more advantages of piezoelectric units (Kwan 2005).

Application in Dentistry

Ultrasound has been applied for therapeutic and diagnostic applications in dentistry for many years as well as for cleaning of instruments before sterilization (Walmsley 1988). The use of ultrasonics or ultrasonic instrumentation was first introduced to dentistry for cavity preparations using abrasive slurry (Postle 1958). Later, a use of an ultrasonic instrument was introduced, to remove deposits from the tooth surface (Zinner 1955). This was improved upon by Johnson and Wilson (1957)to its currently main uses for scaling and root planning of teeth and in root canal therapy (Walmsley 1988; Stock 1991; Walmsley, Laird et al. 1992).

Piezosurgical equipment was also used for retrograde preparation of root canal. It has been also used in the surgical removal of alveolar bone, for harvesting intra oral bone blocks or chips (Horton, Tarpley et al. 1981; Sohn, Ahn et al. 2007), to mobilize the inferior alveolar nerve and in ridge splitting (Bovi 2005; Sakkas, Otten et al. 2008). It was reported that it performs bone cutting with great precision, thus facilitating ridge augmentation and ridge expansion (Palti and Hoch 2002), tooth extraction, and ankylotic tooth extraction (Vercellotti 2004). Piezoelectric sinus membrane elevation can separate the schneiderian membrane without causing perforations (Happe 2007). Piezosurgical equipment appear to be a useful adjunct to the craniofacial surgery armamentarium, but its field of action seems to be restricted to the facial bones (Gleizal, Bera et al. 2007)

Application in Surgically Assisted Orthodontics

The following is a list of the most frequent applications of ultrasound in SAOT, which will be reviewed in detail:

1. Piezosurgery for surgically-assisted rapid maxillary expansion (SARME)
2. Piezosurgery for exposure of palatally impacted canines
3. Piezosurgery to accelerate tooth movement
4. Piezoosteotomy in orthognathic surgery
5. Piezoelectric distraction osteogenesis
6. Posterior maxillary segmental osteotomy concomitant with sinus lift.

1. Piezosurgery for surgically-assisted rapid maxillary expansion (SARME)

Robiony et al. (2007) described the use of the piezosurgical instrument as a minimally invasive device, to allow surgeons to perform all the steps of SARME under local anesthesia.

In a recent research Rana et al. (2013) divided their 30 adult patients who were with an indication for SARME into two groups according to the treatment modality performed. Patients of the first group were treated conventionally with an oscillating saw, while patients of the second group were treated with a piezoelectrical saw. They found that, it is possible to conduct a SARME with the help of an ultrasonic-saw, piezosurgery, which preserves the mucous membrane of the maxilla and is at least as effective and good as the conventional method. The high performance in terms of frequency and power of the piezosurgical device allows it to be used without the aid of any other osteotome, and with the same atraumatic effect on critical vascular structures. The very low amount of bleeding observed during surgery, lack of damage to the main vessels and reduction of postoperative consequences (hematomas and swellings) for patients were striking.

2. Piezosurgery for exposure of palatally impacted canines

In 2004 an alternative method was presented that uses piezoelectricity to minimize trauma to the impacted tooth and the surrounding tissues. They came up with a piezoelectric instrument which controls bleeding during the surgical procedure, ensuring a dry field for bonding to the impacted tooth and eliminating the need for gauze sponges or electrocoagulation. Total surgical time was found to be greatly reduced with this method. (Grenga and Bovi 2004)

3. Piezosurgery to accelerate tooth movement

Vercellotti and Podesta (2007) reported a reduction of the orthodontic treatment time by 60 to 70% after corticotomy performed by means of a piezosurgical micro-saw.

In another study where the divided their sample into two groups; group I (corticotomy group) in which alveolar corticotomies were performed using piezosurgery and group II (non-surgical group) in which non-surgical standard orthodontics technique without corticotomies was done. They concluded that the alveolar corticotomy procedure increases orthodontic tooth movement with accepted degrees of pain and discomfort. Surgical control for piezosurgery was easier than conventional surgical burs for selective alveolar corticotomies (Abbas and Moutamed 2012).

Piezocision, a minimally invasive flapless procedure, combining micro incisions, piezoelectric incisions and selective tunneling that allows for hard- or soft-tissue grafting, was introduce by Sebaoun et al. (2011) as an alternative to corticotomies to accelerate orthodontic treatments.

4. Piezoosteotomy in orthognathic surgery

Landes et al. (2008) compared 90 patient's orthognathic surgery procedures with controls served 90 retrospective patients with conventional saw and chisel osteotomy. Piezoosteotomies were individually designed to interdigitate the jaw segments after repositioning. The pterygomaxillary suture weakened angulated tools; auxiliary chisels were required in 100% of cases for the nasal septum and lateral nasal walls, in 33% for pterygoid processes. The dorsal maxilla as the pterygoid process was easily reduced; 15% mandibular osteotomies required sawing, while the lingual dorsal osteotomy was performed by manual feedback due to limited visibility. Blood loss decreased from average 537±208 ml vs. 772±338 ml. Operation time remained unchanged: 223±70 min vs. 238±60 min for a conventional bimaxillary procedure. Clinical courses and reossification were unobtrusive. It was also reported that alveolar inferior nerve sensitivity was retained in 98% of the piezoosteotomy collective versus 84% of controls at 3 months postoperative testing. They concluded that piezoelectric osteotomy did not prolong the operation time and reduced blood loss and alveolar nerve impairment. Only few patients were found to require additional sawing or chisel. They also concluded that piezoelectric screw insertion and complex osteotomies may be initiated to simplify the procedure and increase segment interdigitation after repositioning as to minimize the osteofixation time and dimensions.

5. Piezoelectric distraction osteogenesis

A piezoelectric device used to treat alveolar bone defects was found to permit perfect osteotomy without palatal flap damage. Also, abundant vascularization from the palatal flap led to successful new bone formation. Furthermore, Piezosurgery is a very convenient device through which it is possible to get direct visibility over entire osteotomies. The only minor limitation is the slightly longer time required for the operation (Lee and Sohn 2007).

6. Posterior maxillary segmental osteotomy concomitant with sinus lift.

Posterior maxillary segmental osteotomy was suggested to be an alternative method for correcting severely extruded teeth. It was reported that the incidence of severe complications can be reduced and the entire process can be completed during a single surgical procedure using a piezoelectric device and elevating the sinus membrane (Hwang, Jung et al. 2011).

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