EFFICIENCY OF PIEZOELECTRIC Vs CONVENTIONAL BUR OSTEOTOMY IN ORTHOGNATHIC SURGERY

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DECLARATION BY THE CANDIDATE

I hereby declare that this dissertation title **"EFFICIENCY OF PIEZOELECTRIC Vs CONVENTIONAL BUR OSTEOTOMY IN ORTHOGNATHIC SURGERY"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. J. A. NATHAN, M.D.S.,** Professor, Department of Oral & Maxillofacial Surgery, Ragas Dental College and Hospital, Chennai.

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CERTIFICATE

This is to certify that this dissertation titled **"EFFICIENCY OF PIEZOELECTRIC Vs CONVENTIONAL BUR OSTEOTOMY IN ORTHOGNATHIC SURGERY"** is a bonafide record of work done by **Dr. G. Sharmishta** under our guidance and to our satisfaction during her postgraduate study period **2013-2016.**

This Dissertation is submitted to **THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY,** in partial fulfillment for the award of the Degree of **MASTER OF DENTAL SURGERY – ORAL AND MAXILLOFACIAL SURGERY, BRANCH III.** It has not been submitted (partial or full) for the award of any other degree or diploma.

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CONTENTS

LIST OF TABLES

LIST OF GRAPHS

LIST OF FIGURES

Introduction

INTRODUCTION

Over the past few years, the field of Oral and maxillofacial surgery in dentistry has undergone a lot of advancements in its daily practice. It has now entered a world of minimally invasive procedures that cause lower morbidity and lesser discomfort to the patients. The success of any of these treatment modalities in oral and maxillofacial surgery depends upon the tools by which the treatment is being carried out. Hence the development of adequate sophisticated instrumentation is an important step for validation of any surgical technique.[17]

Traditional methods include hand cutting instruments such as mallet and chisel followed by micromotor handpiece rotary instruments consisting of different sizes and various shapes of burs and bone saw. But all of these instruments generate a lot of heat during bone cutting as well as exert a considerable pressure in osseous surgeries and require a copious amount of irrigation while performing the procedures. Thus any alteration in temperature is injurious to cells and may cause necrosis of the bone.[60] The amount and quality of any hard tissue removal determines the post-operative outcome in any surgical procedures that are being done.[17] Also when these manual or mechanical instruments were used in the close proximity to the delicate structures like neurovascular tissues, they do not allow for control of the cutting depth and can cause damage to these delicate structures when accidentally contacted.[18]

In order to avoid these unpleasant experiences and to overcome the limitations of manual and traditional mechanical tools, researchers have come up with an advanced and safer therapeutic device which uses the principle of piezoelectric effect and ultrasonic microvibrations. These ultrasonic microvibrations are being used since two decades, but in the last 6-10 years, the experimental applications have been used routinely for various standardized applications in many different fields of surgery as well as in dentistry to make precise and selective cut on the bone without damaging the adjacent soft tissues, blood vessel integrity and nervous tissue.[17,18,60,61]

Piezosurgery is one such innovation to incorporate these properties of ultrasonics and inverse piezoelectricity.[47,61] Piezosurgery is a newer alternative technique and its applications have already been well established and documented for performing various surgical procedures in different parts of the body like rhinoplasty, head and neck surgery, neurosurgery, orthopaedic surgery, plastic and reconstructive surgery, mastoidectomy, cranioplasties etc. Particularly in the field of oral surgery Piezosurgery has been used for various bone related procedures such as making bony windows for sinus lift procedures,[59] lateralization or transpositioning of the inferior alveolar nerve,[44] atraumatic tooth extractions,[35,40] alveolar ridge expansions,[42] implantology, bone graft harvesting,[10,50] cyst and tumor enucleation,[53] TMJ ankylosis, distraction osteogenesis, cranioplasties,[13,36] orthognathic surgery,[11,24,37] etc.

The main advantages which have been summarized by many researchers are:[18,19,21,24,61]

a. Excellent visibility of the surgical field while performing the procedures.
b. Minimal amount of bleeding and bone removal achieved.
c. The cavitational effect efficiently removes the osseous detritus and does not harm cell viability.
d. Lesser heat and vibration impact exerted on the bone.
e. Precise and geometric cutting of the bone.
f. Good bony contact or inter-digitation between the osteotomized segments after repositioning is done.
g. Reduced post-operative swelling and hematoma formation.
h. Maintains vessel integrity.
i. Minimal nerve damage with faster nerve healing and sensory recovery was achieved in shorter duration of time.
j. Good bone healing and re-ossification due to reduced marginal necrosis.

Similarly no innovation goes without any drawbacks and disadvantages which include:

a. Time taken by piezosurgery for performing osteotomy procedures is longer and the duration increased by 3 or 4 times in dense cortical bone osteotomies.

b. Breakage of the inserts occurs often, hence it is mandatory to maintain a stock of inserts while performing the osteotomy procedures.

c. Increased cost than mechanical osteotomies.

Among various surgical phases, Orthognathic surgery is one such technique sensitive treatment modality that is used to correct maxillofacial deformities which involves sectioning of the bone in close proximity to the delicate structures. This helped in the improvement of the dentofacial harmony by enhancing the function and appearance but, it does not go without any unwanted side effects like intra-operative blood loss, hematoma formation, pain, swelling, paraesthesia, marginal bone necrosis and impaired bony regeneration which occurs due to excessive heating caused by the use of rotary instruments. In conclusion, the orthognathic surgical correction of the dentofacial skeleton produces an unpleasant experience for the patient.

Taking into account the described advantages of the piezosurgery, we have used this instrument for a split mouth prospective clinical study and performed osteotomies in twelve patients who required orthognathic surgical procedures. On one side (left) of each patient we used piezosurgery for the purpose of osteotomy and on the other side (right) we used the conventional bur osteotomy and compared their intraoperative and postoperative effects between the two groups.

Aims & Objectives

AIMS AND OBJECTIVES

The goal of this clinical study was to compare and evaluate the effects of Piezosurgery Vs the Conventional Bur osteotomies in patients undergoing Orthognathic surgery.

The intra-operative and post-operative outcomes were assessed in terms of:

a. Blood loss
b. Pain
c. Swelling
d. Nerve impairment.

History & Physics

HISTORY & PHYSICS

Piezoelectricity was discovered in 1880 by French physicists, the two brothers **Jean** and **Marie Curie.** The word Piezoelectric is derived from the Greek language ‘piezo’ or ‘piezein’ which means **press** or to squeeze and ‘electric’ or ‘electron’ means **amber**, an ancient source of electric charge. It means when mechanical constraint or pressure is applied it results in electricity thus producing ultrasonic waves. Piezoelectricity is the electric charge that accumulates in certain crystals such as quartz, ceramics etc and in certain biological forms like bone, DNA and various proteins in response to the applied mechanical stress. However, the piezoelectric surgery unit uses the inverse piezoelectricity which is the opposite phenomenon where, when an electric current is applied to a crystal, it results in a mechanical deformation in the crystals which expand and contract alternatively to produce ultrasonic waves.[18,19,47,60]

Ultrasonic waves are mechanical waves that are biologically harmless and inaudible to us. When a simple phenomenon of agitation occurs, it induces disorganization and fragmentation of the different bodies. These ultrasonic waves thus can cleave easily any solid-solid interfaces by differential vibrations and any solid-liquid interfaces by cavitation.[47,51]

In 1988, **Tomaso Vercellotti** an Italian oral surgeon is the one who have modified the conventional ultrasonic technology and developed the idea of first piezoelectric bone surgery.[21,61] The ultrasonic microvibrations produced by the piezoelectric surgery unit occurs at a frequency of 24-29 khz which selectively cuts only the mineralized tissues. The damage to the adjacent soft tissues and neurovascular tissue occurs only when frequency above 50 khz is used. The ultrasonic tips vibrate linearly at an amplitude of 60-200 mm/sec horizontally and a 20-60 micrometers in a vertical motion which is targeted only towards the mineralized tissue. Depending on the resistance encountered by the tip, the vibration amplitude can be adjusted between 30-60 micro meters which allows for constant adaptation of the power. The oscillating tip also produces constant and continuous coolant ranging from 0-60 ml/min which produces the cavitation effect. The power of the device is adjusted at 5W.

Cavitation is the micro-boiling phenomenon which induces the process of vaporization, bubble formation and implosion as a result of ultrasonic vibrations.[18,47] This effect thus washes away the detritus, maintains the bone temperature, regulates hemostasis and clears the field of surgery.

Piezo Inserts:

Piezosurgery inserts are the ones mainly screwed onto the handpiece for various purposes in the field of dentistry as well as medicine. They are coated with titanium nitride or sometimes diamond to increase the hardness of the inserts and are available in various sizes, shapes and materials. They are mainly classified into 4 types based on their purpose of usuage namely: for periodontal surgery, for dental avulsions, for opening the maxillary sinus and lifting the membrane and those that cut through the bone and remove the fragments.[18, 47]

Review of Literature

REVIEW OF LITERATURE

Tomaso Vercellotti et al (2001)[59] presented a new surgical technique using Piezosurgery that radically simplified maxillary sinus surgery, thus avoiding perforation of the membrane. This technique allowed a much greater success rate than any other traditional methods for sinus elevation without causing perforations.

Vercellotti T (2004)[61] described piezoelectric bone surgery, also simply known as Piezosurgery, is a new technique for osteotomy and osteoplasty utilizing an innovative ultrasonic surgical apparatus. This technique was created and developed in response to the need for reaching major levels of precision and safety in bone surgery, as compared to that available by the usual manual and motorized instruments. The instrument which offers these results, known as Mectron Piezosurgery Device, is characterized by Piezoelectric ultrasonic vibrations of a frequency of 29kHz and a range between 60-200Hz. The micrometric vibration ensures precise cutting action and at the same time maintains blood-free site because of the physical phenomenon of cavitation. Also makes the instrument more manageable and allows major inter-operative control with increase in safety especially in anatomically difficult areas.

Siervo S et al (2004)[55] Presented a series of case reports of the possible uses of Piezosurgery in the oral cavity over a period of 18 months.

The final result is a definite clinical advantage with regard to the cut precision, the sparing of vital nervous tissues and a better visualization of the surgical area.

Lambrecht JT (2004)[34] demonstrated four examples: tooth extraction before implantation under minimal grinding of bone, gaining bone for peri-implant transplantation, preparation for sinus lift, exposing the inferior alveolar nerve using Piezosurgery and showed that this method has a remarkable addition to the intraoral operation techniques.

Georg Eggers et al (2004)[23] evaluated the efficacy of osteotomy done with Piezosurgery on delicate bony structures in the craniofacial region, and found this device to be very useful when, exact cutting of the thin bones is essential without damage of the adjacent soft tissues.

M. Robiony et al (2004)[37] introduced the use of Piezoelectric surgery for multipiece maxillary osteotomies, to overcome many of the complications of this delicate surgery on hard and soft tissues. The result of this evaluation suggests the high safety and precision of the osteotomy cuts and there is no osteonecrosis damage. Also it worked only on the mineralized tissues, sparing soft tissues and their blood supply.

Kahnbery KE et al (2005)[31] had done a retrospective examination of the clinical and radiographic incidence and frequency of injuries to teeth and their surrounding adjacent tissues adjacent to the interdental osteotomies in conjunction with segmentation of the maxilla on 82 patients in between 1992 and 1998. Results showed that there were only a small number of complications such as osteolytic processes, marginal bone destruction, root resorption or mechanical injuries to the teeth.

Kramer et al (2005)[33] reported the occurrence of intra or perioperative complications in a series of 1000 consecutive Le Fort I osteotomies performed within a 20-year period. In total, 64 (6.4%) patients experienced complications. Anatomical complications affected 2.6% patients, 1.6% with a deviation of the nasal septum and 1.0% with non-union of the osteotomy gap. Extensive bleeding that required blood transfusion occurred in 1.1% patients exclusively after bimaxillary corrections and in 1 patient a ligation of the external carotid artery became necessary. Significant infections such as abscesses or maxillary sinusitis occurred in 1.1% patients. No patient experienced an osteomyelitis. Ischemic complications affected 1.0% patients, including 0.2% who experienced an aseptic necrosis of the alveolar process and 0.8% who under critical revision, were affected by retractions of the gingiva. 0.5% patients experienced an insufficient fixation of the osteosynthesis material. The authors concluded that patients with major anatomical irregularities should be informed about an enhanced risk of Le-Fort I osteotomies.

R. M. Gruber et al (2005)[52] performed a pilot study on 7 patients with class II or class III malocclusion who underwent bilateral sagittal split osteotomies of the mandible using ultrasonic surgery and compared to the conventional techniques using saws, chisels and burs. Results showed that thought the ultrasonic osteotomy was time consuming, it provided good blood free surgical field and subjective neurosensory disturbances showed a continuous decrease from 57.1% 2months after surgery to 14.3% after 5 months and to 7.1% at the end of 7 months.

Chiriac G et al (2005)[11] have investigated the influence of the new Piezoelectric device, over the harvested autogenous bone chips from intra-oral sites, on chip morphology, cell viability and differentiation. A total of 69 samples of cortical bone chips were gained by either piezoelectric or conventional rotary drills. Results of the morphometric analysis revealed a statistically more voluminous size of the particles collected with Piezosurgery than those collected with conventional rotating devices.

Stefan stubinger et al (2005)[56] studied on various intraoral procedures and reported series of cases using Piezosurgery and concluded that the instrument allows exact, clean and smooth cut geometries without damaging the soft tissues during the surgery. Postoperatively, excellent wound healing, with no nerve injuries, is observed. Because of its highly selective and accurate nature, its use may be extended to more complex oral surgery cases, as well as to other interdisciplinary problems.

Geha et al (2006)[22] evaluated the sensitivity of the inferior lip and chin both subjectively and objectively following mandibular bilateral sagittal split osteotomy using piezosurgery on 20 patients. Results showed that piezosurgery maintained the anatomical integrity of the inferior alveolar nerve in all cases and observed normal results for the different tests at 10days as 90%, 82% and 70% respectively for pin-prick, light-touch sensation and 2-point discrimination. They concluded that the inferior alveolar nerve function was recovered within as early as 2 months of time.

B. Kotrikova et al (2006)[6] presented a new surgical technique of osteotomy (Piezosurgery) that can be applied in high risk cranial osteotomy patients avoiding perforation of the dura matter. Due to the device's selective cut of mineralized structures, even in case of accidental contact the dura matter remained undamaged.

Beziat et al (2007)[7] study suggests that there was good functional results without any damage to the soft tissues were observed by employing ultrasonic osteotomy in the following craniofacial surgical procedures: 144 Le Fort I osteotomies, 140 palatal expansions after Le Fort I osteotomies and 140 bilateral sagittal split osteotomies, 2 Le Fort III osteotomies for treatment of crouzon syndrome in 2 patients, 12 cases of unicortical calvarial bone grafting, removal of superior orbital roof in 25 cases and 10 cases of orbital cavity tumor.

M. Robiony et al (2007)[38] illustrated the use of Piezosurgery for all osteotomies of surgically assisted rapid maxillary expansion (SARME). The procedure including pterygo-maxillary detachment can be safely done under local anesthesia. Other advantages include minimal risk to the critical anatomic structures, minimal intraoperative bleeding and postoperative swelling and minimal thermal damage to bone surfaces.

Tomaso Vercellotti (2007)[58] tested the piezosurgery device on 20 patients affected by otosclerosis, for bone tissue management in otology surgery and in particular in stapedotomy and the external auditory duct posterior wall. The test results showed up that a normal tympanic membrane at 15 days after surgery which was contributed due to device's accuracy and selectivity which rendered it superior to conventionally rotating instruments in otology surgery. Also it allowed exact, clean and smooth cut geometries without any visible injury to the adjacent soft tissues.

Alberto Gonzalez-Garcia et al (2007)[1] stated that Piezoelectric bone surgery is based on ultrasonic vibration of a device functioning as an osteotome. It is well suited for osteotomy in alveolar distraction osteogenesis. It allowed for precise cutting without provoking lesions of adjacent soft tissues and at the same time offering excellent visibility within the surgical field.

Constantin A. Landes et al (2008)[12] used Piezosurgery as a substitute for the conventional saw in orthognathic surgery and evaluated 50 patients regarding the operative technique, blood loss, time requirement and nerve and vessel integrity. They have concluded that Piezoelectric osteotomy reduced blood loss and inferior alveolar nerve injury at no extra time investment. Also

Piezosurgical bone osteotomy permitted individualized cut designs, enabling segmental inter-digitation after repositioning.

Francesco Sortino et al (2008)[20] compared the postoperative outcome in mandibular impacted third molars treated by Piezoelectric surgery and by rotatory osteotomy technique in 100 patients. Results showed that the piezoelectric technique produced a reduced amount of facial swelling and trismus 24 hours after surgery, when compared with the rotatory osteotomy technique.

C. A. Landes et al (2008)[8] assessed the piezo-osteotomy in orthognathic surgery over the alternative conventional saw and chisel osteotomy regarding handling, time requirement, nerve and vessel integrity on 90 patients. Results showed that the Piezo-osteotomy did not prolong the operation and reduced blood loss, and reduced alveolar nerve impairment. Also it increased the segment inter-digitation after repositioning and minimized the osteofixation time and dimensions.

Philippe Leclercq (2008)[46] presented the applications of Piezosurgery in detail and discussed their advantages and disadvantages compared with other techniques. This study confirmed that this ultrasonic device belongs to the category of tools, which transform delicate operations into easy and perfectly mastered procedures.

Mauro Labanca et al (2008)[42] described Piezoelectric surgery as a minimally invasive, innovative ultrasonic technique for safe and effective osteotomy or osteoplasty, that lessens the risk of damage to surrounding soft tissues and important structures such as nerves, vessels and mucosa when compared to the traditional rotating instruments. Because of the absence of macro vibrations, ease of use and control and safer cutting, particularly in complex anatomical areas, it reduced the damage to osteocytes and permits good survival of bony cells during harvesting of bone. It seems to be more efficient in inducing earlier increase in bone morphogenetic proteins, control the inflammatory process better and stimulates remodeling of bone as early as 56days after treatment.

Philippe Leclercq et al (2008)[47] presented the physical, technologic and clinical aspects and discussed the most promising applications of piezoelectric surgery.

Nikolaos Sakkas et al (2008)[44] reported a case of 74year old women with pain and hyperaesthesia of the right inferior alveolar nerve caused by the dental prosthesis in whom the caudal transposition of the mental nerve by Piezosurgery confirmed its safe use, by objective postoperative neurosensory controls of the lower lip showing normal nerve function 2months later.

Kagan Degerliyurt et al (2009)[30] demonstrated a new bone lid technique with Piezosurgery to preserve inferior alveolar nerve, vascular tissues and surrounding dental tissues. As the Piezoelectric surgery uses microvibrations at ultrasonic frequency soft tissues will not get damaged even upon accidental contact with the cutting tip.

Escoda-Francoli J et al (2010)[17] described some of the applications of ultrasound in bone surgery, based on the presentation of two clinical cases. Results of the study showed that the Piezosurgery instrument produced selective sectioning of the mineralized bone structures, lessened the risk of sinus membrane laceration and causes less intra and postoperative bleeding.

Angelo Salami et al (2010)[3] prime aim was to determine the efficacy of the Piezoelectric device in revision mastoidectomy surgery for chronic otitis media on a total of 30 patients. Results proved that the device had real advantages, because it was possible to perform blind cutting of bone with fewer precautions necessary for soft tissues such as facial nerve, lateral sinus and dura matter, and with no evidence of audio-vestibular deficit or side effects.

Camargo Filho GP et al (2010)[10] did a comparative study between two autogenous graft techniques using Piezosurgery for sinus lifting on 9 rabbits. Assessment of operative procedures led to the conclusion that, piezoelectric surgery has proven to be a safe tool in the surgical approach to the maxillary sinus of rabbits, allowing sinus membrane integrity to be maintained during surgical procedures.

Antonio Barone et al (2010)[4] compared and investigated, in a randomized and controlled clinical trial on 26 patients, the use of ultrasound bone surgery device and the use of rotary instruments in lower third molar extractions. Results showed that there was reduced postsurgical trismus, decreased swelling and reduced intake of analgesics after surgery in the ultrasound bone surgery group when compared to the conventional group.

Pier Francesco Nocini et al (2010)[48] has demonstrated on 11 consecutive patients, the preliminary experience for the segmentation of the vascularized bone flaps with Piezosurgery. The resulted data exhibited that, it is a valuable alternative to conventional cutting methods for the following reasons: 1) it improves the intraoperative safety of the procedure, ensuring an adequate periosteal blood flow to the bone segments, 2) it does not increase the overall operative time, 3) it does not interfere with bone flap survival and bone healing.

M. A. Nusrath, K. R. Postlethwaite (2011)[36] added a technical note on the usefulness of Piezosurgery in calvarial bone grafts and for release of the inferior alveolar nerve in sagittal split osteotomy. The device has advantages over traditional methods as it allowed for precise cutting and caused minimal wastage of bone with minimal damage to soft tissues.

Pineiro-Aquilar A et al (2011)[49] conducted a systematic review of the published data regarding intraoperative blood loss during orthognathic surgical interventions, including Le Fort I osteotomy, mandibular ramus osteotomy, and both combined. Results have shown that the intraoperative bleeding observed in patients during the procedures was about 436.11 ml and was less than the limits set for blood transfusion and surgeons should always be prepared for heavier bleeding by reserving blood at a blood bank or preparing of autotransfusion.

D. Baldi et al (2011)[14] found that Piezosurgery yielded best results for sinus floor augmentation installed with tapered implants using a 1-step crestal approach, where the residual bone is <7.5mm. This technique allowed precise and selective cutting of mineralized tissues, thus limiting the risk of Schneiderian membrane perforation. Also stated that piezosurgery provided less discomfort to the patient and greater convenience for the surgeon.

Jae Ho Hwang et al (2011)[27] developed a technique using a Piezoelectric device to correct a collapsed occlusal plane. In this study the Posterior maxillary segmental osteotomy was done concomitantly with sinus lift using Piezosurgery which resulted in preservation of the integrity of the sinus membrane and the posterior superior alveolar nerve.

G. Pavlikova et al (2011)[21] summarized current knowledge and experience with Piezosurgery, as promising and soft tissue sparing system while cutting bone. It is a technical modality that can be used for different aspects of bone surgery with a rapidly increasing number of indications throughout the whole field of surgery. The main indications in oral surgery are sinus lift, bone graft harvesting, periodontal surgery, IAN decompression, cyst removal, dental extraction, osteotomies and osteogenic distractions.

Pooja M Pharne et al (2012)[50] conducted this study to see the efficacy and safety of ultrasonic bone surgery device in harvesting intraoral autogenous bone grafts and to compare it with manual and rotary instruments. It was concluded that Piezosurgery is very easy and safe to use for harvesting intraoral autogenous bone grafts compared to manual and rotary instruments.

C. Von See et al (2012)[9] used three output levels of oscillations that were predefined by the Piezo-electric device and investigated the perfusion in the osseous vessels in close vicinity to Piezo-electric bone cutting. Using repeated intra-vital fluorescence microscopy the blood flow was assessed, and concluded that blood flow at all three levels of oscillation was constant and no vessel had been occluded. Hence application of Piezosurgery does not cause the formation of microthrombi in the bone.

Manoj Goyal et al (2012)[40] compared the use of conventional rotary handpiece and a piezosurgical unit for extraction of lower third molars. Pain, trismus and oedema were evaluated at days 1, 3, 5, 7 and 15. Results showed that there was significant reduction in pain, trismus and swelling in the Piezotome group than the conventional rotary group.

Islam T Abbas and Gamal M. Moutamed (2012)[26] demonstrated the alveolar corticotomy procedure done with Piezosurgery is associated with minimal morbidity and offers a promising means of improving and simplifying orthodontic therapy for patients. Surgical control for piezoelectric surgery (PES) was easier than conventional surgical burs for selective alveolar corticotomies. The force necessary to produce a cut was much less compared to the surgical burs. Increased temperatures during bone cutting with PES was avoided which reduces the risk of bone damage as a result of overheating.

Majeed Rana et al (2013)[39] evaluated the clinical comparison between Piezosurgery versus Oscillating Saw and Chisel osteotomy in surgically assisted rapid maxillary expansion. Results showed that efficient cutting of the mineralized tissues with minimal trauma to soft tissues and decreased blood loss was achieved with Piezo-osteotomy when compared to the other osteotomy groups.

Jorge Jefre et al (2013)[29] reported three cases treated with a novel, flapless approach for minimally invasive rapid orthodontics and it includes radiographic-guided micro incisions and localized piezoelectric corticotomies. The clinical implications of this technique is that, it is an atraumatic procedure, maintains gingival contour, decreases risk of resorption as it is a flapless procedure and healing occurs without edema or patient discomfort.

Mansur Rahnama et al (2013)[41] discussed the wide range of surgical procedures that can be done using Piezosurgery as an alternative method of minimally invasive surgery. Also the study added that Piezosurgery allows a more successful and complication-free surgical result for a less experienced surgeon.

Elio Hitoshi Shinohara et al (2013)[16] discussed the use of Piezoelectric device for the initial detachment of the nasal mucosa in the maxillary Le Fort I osteotomy contributed to decrease in mucosal tear, which ultimately led to reduction of the bleeding postoperatively after the restoration of the blood pressure.

Y. Gulnahar et al (2013)[63] compared Piezosurgery and conventional surgery by heat shock protein 70 expression (Hsp70). This study examined the expression of Hsp70 as a potential biomarker of immediate post-operative stress in patients undergoing two different surgical procedures of different severity. Expression of Hsp70 both at mRNA and at protein level in the conventional group was two-fold higher than that of the Piezo group. This suggests that tooth movement by the Piezo method induces relatively lower stress in the alveolar bone.

Amelie Rougeot et al (2013)[2] used Piezosurgery for external dacrocystorhinostomy and discussed that it enabled precise and safe bony cutting with no soft tissue injury, particularly to the nasal mucosa and the skin, which causes scars and the operative field remained bloodless.

Elif I. Keser and Serge Dibart (2013)[15] illustrated how Piezocision can be used sequentially in selected patients to produce outcomes that are timely and satisfactory. This minimally invasive technique was designed to achieve rapid orthodontic tooth movement without the downside of extensive and traumatic conventional surgical approaches. Also this new technique can be combined with various orthodontic treatment modalities to satisfy today's adult patient population.

Luigi Piersanti et al (2014)[35] compared the discomfort and surgical outcomes of a Piezosurgery device with those of rotatory instruments in lower third molar extraction and observed that the Piezosurgery seems to be associated with less postoperative discomfort and yielded better results for swelling.

Jing Ge et al (2014)[28] demonstrated four different osteotomy methods using Piezosurgery which provide effective ways to remove complicated mandibular third molars successfully, enhance the efficiency and lower the rate of the major complications.

Sergio Olate et al (2014)[54] showed that the segmented Le Fort I osteotomies with Piezoelectric systems can be performed with a low risk of injury to soft tissues and in a time probably less than 50 minutes for the maxillary osteotomy.

Mohammed Almohaimeed (2014)[43] reviewed the various treatment applications like rapid maxillary exposure of palatally impacted canines, tooth movement acceleration, orthognathic surgery, distraction osteogenesis, posterior maxillary segmental osteotomy with sinus lift that have been used in surgically assisted orthodontic treatment using Piezosurgery.

Paolo Scolozzi and Georges Herzog (2014)[45] described total mandibular subapical osteotomy and Le Fort I osteotomy done using Piezosurgery and computer-aided designed and manufactured surgical splints in the management of severe mouth asymmetry in parry-romberg syndrome. The use of this Piezosurgical osteotomy minimized the risk of injuring inferior alveolar nerve in close proximity to the osteotomy procedure and also prevented dental root damage.

Guiseppe Spinelli et al (2014)[24] hypothesised that Piezoelectric surgical device could permanently replace traditional saws in conventional orthognathic surgery. Based on this hypothesis a split-mouth study was done and results showed that Piezoelectric device allows surgeons to achieve better results compared to the traditional saw, especially in terms of intraoperative blood loss, postoperative swelling and nerve impairment.

Esha agarwal et al (2014)[18] emphasized on the historical, clinical and biological aspects of Piezosurgery contributing to beneficial dental health over the traditional tools. It ensured the 3 ‘P’s that is predictability, less post-operative pain and increased patient’s compliance.

F. Carini et al (2014)[19] reviewed last 10 years publications about Piezo-electric bone surgery in dentistry, the analysis of which revealed, reduced surgical trauma, cut precision and selectivity and speed of learning guaranteed by piezoelectric devices compared to traditional ones.

Hitoshi Yoshimura et al (2014)[25] Reported the recovery of the nerve function was achieved at 2 weeks post-operatively and the duration of neurosensory disturbance was much shorter than conventional methods in a case of 70 year old male, with osteoradionecrosis in whom Piezosurgery-assisted transposition of the inferior alveolar nerve (IAN) was done.

Katharina A. Ponto et al (2014)[32] assessed the efficiency of Piezosurgery for orbital decompression surgery in thyroid associated orbitopathy in 40 patients. The author has concluded that it could cut the bone selectively and precisely and reduced the invasiveness of surgery.

Sabrina Pappalardo, Renzo Guarnieri (2014)[53] results of this study which was done on 80 patients suggest that Piezosurgery may be considered effective in cyst enucleation compared to traditional procedures with burs, since it grants the patients significantly less post-surgical pain and swelling.

Constantin Landes et al (2015)[13] evaluated the benefit of Piezo-osteotomy in cranioplasty of craniosynostosis in 19 patients and results showed that Piezo-osteotomy to be less traumatic than conventional saw and chisel osteotomy in the evaluated parameters.

Materials and Methods

MATERIAL AND METHODS

The institutional review board had evaluated and approved the study. All the patients were explained about the study and informed consent was obtained.

Patients:

Twelve patients from the Department of Oral & Maxillofacial Surgery, Ragas Dental College and Hospital, Chennai who required orthognathic surgical corections of their presenting dento-facial deformities were included in the study during the period between January 2014 and September 2015.

Inclusion criteria:

- Patients with dento-facial deformities who required orthognathic surgical procedures.
- Patients between 18-30 years of age.

Exclusion criteria:

- Non-consenting patients.
- Patients who had recent infection or swelling.
- Patients with pacemakers.
- A previous history of maxillo-facial trauma, orthognathic surgery or any other reconstructive facial surgeries.
- Patients with any underlying systemic or neurological disorders.

Materials:

Piezosurgical instrument (Mectron Medical Technology, Italy) consists of a handpiece, a foot pedal and a base unit which are connected to a power source. Physiological and sterile 0.9% sodium chloride solution has been used for generous irrigation which was setup at level 4 or 5. All the surgeries were done using the "bone" or "booster" mode settings which had three levels corresponding to cortical, spongious and special powers respectively. For the study group we used the OT7, OT8R and OT8L inserts screwed onto the handpiece.

A micromotor with straight handpiece and tungsten carbide burs no.559, no. 702 and no.703 screwed onto it were used on the control side of the patient.

Surgical method:

All the 12 orthognathic surgeries were done by a single senior surgeon with two assistants with naso-endotracheal intubation under general anesthesia. Patient was prepared and draped. After throat pack placement, intra-oral betadine saline irrigation was done. In all the 12 patients the right side was assigned to conventional bur osteotomy and the left side was assigned to piezosurgical osteotomy.

Bilateral inferior alveolar nerve blocks were given using 1:80,000 concentration local anesthetic solution with adrenaline in the mandible and in the maxilla the mucosa was infiltrated with local anesthesia from molar to molar bilaterally.

The mouth was kept wide open using bite blocks and the incision was carried out using an electrocautery starting superiorly at the two-thirds up the anterior border of the ramus to inferiorly lateral to the external oblique ridge in the vestibule extending distal to the second premolar. Then the subperiosteal dissection was completed and the entry of the nerve at the lingula was traced. At first the surgeon made the medial cut using the tip of the surgical instrument by penetrating into the cortical bone 2 to 3mm above the lingula without harming the inferior alveolar nerve followed by the buccal osteotomy that was performed perpendicular to the occlusal plane between the first and second molars upto the lower border of the mandible. Then the medial and buccal osteotomies were connected by a horizontal osteotomy. All the osteotomies were deepened using a curved chisel starting from the superior osteotomy to the inferior osteotomy in a progressive fashion, malleting constantly changing the direction of the chisel according to the contour of the mandible on the right side whereas, all the osteotomy cuts on the left side of the mandible were deepened using the piezo insert OT7. (All the mandibular osteotomies were performed using OT7 and OT8L piezo inserts on the left side of the patient and tungsten carbide burs no.559 and bur no.703 were used for the right side osteotomies).

Then using the vestibular incision circumorally from first molar to first molar, the periosteum in the maxilla was prepared for the Le Fort I osteotomy. Both the piezosurgery insert and the traditional burs were used on their respective sides starting the osteotomy from the zygomaticomaxillary buttress and terminated anteriorly at the pyriform aperture below the inferior turbinate of the nose. Then a retractor was placed at the junction of the maxilla with the pterygoid plate and under direct vision the posterior osteotomy was performed by directing the osteotomy inferiorly and medially as it proceeded from the zygomaticomaxillary buttress to the junction of the maxilla and pterygoid plates. For all the maxillary osteotomies on the left side OT7 and OT8L piezo inserts were used, whereas on the right side bur no. 559 and bur no. 702 or 703 were used. This completed all the bony osteotomies using the prescribed instrumentation. The nasal septum and the lateral nasal walls in all the cases were osteotomized using septal chisel and lateral nasal chisels respectively and the downfracturing of maxilla was completed. Using a flame shape bur the desired amount of bone was removed or smoothened from the nasal floor of the maxilla and the segments were stabilized using L – plates under IMF with intermediate splint in between the maxilla and mandible.

Once the maxilla is set in the desired position the IMF was released and then the bilateral sagittal split was completed. Final Occlusion and condylar positions were checked and the mandible was fixed using final acrylic splint under IMF to the already repositioned maxilla.

All the surgical wounds were closed using 3-0 vicryl and intraoral betadine saline irrigation was done. Finally all the patients were extubated uneventfully. Post-operative medications including antibiotics, analgesics and steroids were given as per standardization for all the patients.

The clinical examinations were carried on 1st, 3rd and 7th postop days and at 1st, 3rd and 6th months after the surgery. All the patient's preoperative and postoperative photographs and X-rays were taken for comparison of their appearance before and after the surgery.

PARAMETERS:

Each of the device's characteristics were analysed on the basis of the literature reports and the following intraoperative and postoperative parameters were assessed.

Intraoperative blood loss: (Table 1)

The blood loss was evaluated in milliliters collected in the calibrated suction instrument for each surgical procedure. The amount of blood loss was calculated by subtracting the premeasured saline used for irrigation from the total amount of drain collected for each osteotomy.

Pain: (Table 2 & 3)

Pain was evaluated with the help of numeric pain rating scale ranging from 0 for "no pain" to 10 for "severe pain" and Wong-Baker faces pain rating scale ranging from 0 for “no hurt” to 10 for “hurts worst” on the 1st, 3rd and 7th postoperative days.

Swelling: (Table 4)

Swelling was evaluated preoperatively and post operatively by marking mandibular angle (gonion), tragus of the ear, lateral canthus of the eye, ala of nose, commissure of the lip and pogonion. Using mandibular angle as the base point, all the distances were measured to the above mentioned points using measurement tape in millimeters preoperatively and on 1st, 3rd and 7th days and 1 month postoperatively.

The sum of all these measurements were taken for the assessment of the facial swelling.

Paraesthesia: (Table 5, 6, 7 & 8)

Neurosensory evaluation was done for both right and left sides of the mandible individually over the inferior lip, chin and body by using light touch sensation, pin-prick test and the static 2-point discrimination (Weber) test on 1st & 7th days, 1 month, 3 months and 6 months postoperatively. Then the Patients were also asked to evaluate their personal perception (subjective evaluation) of sensory recovery and grade their responses at 1st and 7th days, 1st and 3rd month postoperatively as in the table 8.

1. Light touch sensation was evaluated by doing the cotton wool sensation test over the chin, inferior lip and body of the mandible

and graded as score 1 if the test result was "positive" and graded as score 0 if the test result was "negative". (table 5)

2. Pin – prick neurosensory evaluation was done using a sterile probe over the chin, inferior lip and the body of the mandible and recorded as score 1 if the test result was "positive" and as score 0 if the test result was "negative". (table 6)
3. Static two – point discrimination test was done using a divider which had parallel pair of probes which were spaced at a distance of 2mm and a measuring scale. The test was done by asking the patient to close his or her eyes and notify the difference between the one point and two points of the divider at regular fixed intervals ranging between 2mm to 8mm. The value was recorded in millimeters for atleast 3 out of 5 responses at different intervals of lengths used. If there was no loss of sensation at all then a highest value of score "5" was given whereas, a score of "0" indicated a complete loss of sensation (paraesthesia). (table 7)

Table 1: Intra-Operative Blood Loss

MAXILLA

	TOTAL AMOUNT OF SALINE (S) USED (ml)	TOTAL AMOUNT OF DRAIN (TD) COLLECTED (ml)	BLOOD LOSS (TD – S)ml
RIGHT SIDE			
LEFT SIDE			

MANDIBLE

	TOTAL AMOUNT OF SALINE (S) USED (ml)	TOTAL AMOUNT OF DRAIN (TD) COLLECTED (ml)	BLOOD LOSS (TD – S)ml
RIGHT SIDE			
LEFT SIDE			

Table 2: Wong-Baker Faces Pain Rating Scale

Table 3: Numeric Pain Rating Scale

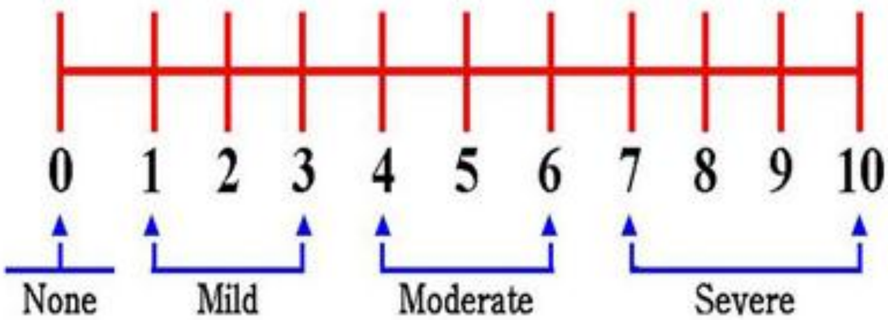
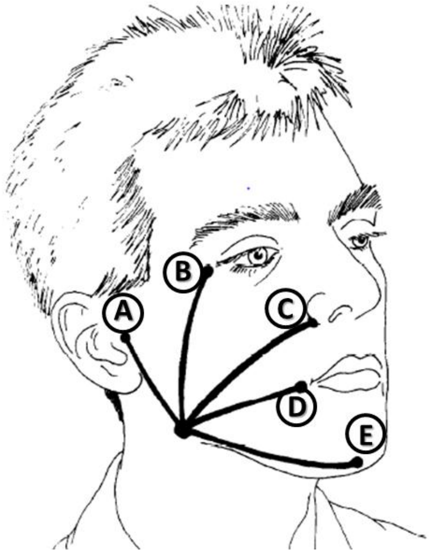


Table 4: Swelling



	Right side						Left side					
	A	B	C	D	E	T	A	B	C	D	E	T
Pre-operative												
Post-operative day 1												
Post-operative day 3												
Post-operative day 7												
1 Month post-op												

T-Total Sum of A+B+C+D+E

Table 5: Light Touch Sensation

	Right Side – conventional bur technique (positive or negative)	Left Side - piezosurgery (positive or negative)
1st Postoperative Day		
7th Postoperative Day		
1st Postoperative Month		
3rd Postoperative Month		
6th Postoperative Month		

Positive score - 1 and negative score – 0

Table 6: Pin – Prick Test

	Right Side - conventional bur technique (positive or negative)	**Left Side - piezosurgery (positive or negative)**
1st Postoperative Day		
7th Postoperative Day		
1st Postoperative Month		
3rd Postoperative Month		
6th Postoperative Month		

Positive score - 1 and negative score – 0

Table 7: Static Two Point Discrimination Test Or Weber Test

	Conventional Bur Technique (score 0 to 5)	**Piezosurgery (score 0 to 5)**
1st Postoperative Day		
7th Postoperative Day		
1st Postoperative Month		
3rd Postoperative Month		
6th Postoperative Month		

Postoperative values	**Corresponding score**
No difference	5
1 – 2 mm	4
2 – 3 mm	3
3 – 4 mm	2
5 – 6 mm	1
>6 mm	0

Table 8: Subjective Inferior Alveolar Nerve Sensitivity Evaluation on each side by the Patient at 1st and 3rd postoperative months.

Duration	**Levels of Response**	**Grade for Right Side – Conventional Bur Technique**	**Grade for Left Side - Piezosurgery**
1st postop day	▪ Absent sensation, anesthesia – **1** ▪ Severaly altered sensation, paresthesias – **2** ▪ Moderately altered or slightly reduced sensation – **3** ▪ Mildy reduced or subnormal sensation – **4** ▪ Normal sensation - **5**		
7th postop day	▪ Absent sensation, anesthesia – **1** ▪ Severaly altered sensation, paresthesias – **2** ▪ Moderately altered or slightly reduced sensation – **3** ▪ Mildy reduced or subnormal sensation – **4** ▪ Normal sensation - **5**		

1st postop month	▪ Absent sensation, anesthesia – **1** ▪ Severaly altered sensation, paresthesias – **2** ▪ Moderately altered or slightly reduced sensation – **3** ▪ Mildy reduced or subnormal sensation – **4** ▪ Normal sensation - **5**		
3rd postop month	▪ Absent sensation, anesthesia – **1** ▪ Severaly altered sensation, paresthesia – **2** ▪ Moderately altered or slightly reduced sensation – **3** ▪ Mildy reduced or subnormal sensation – **4** ▪ Normal sensation - **5**		

Figures

Fig. 1: PIEZOSURGERY UNIT

Fig. 2: INSERTS

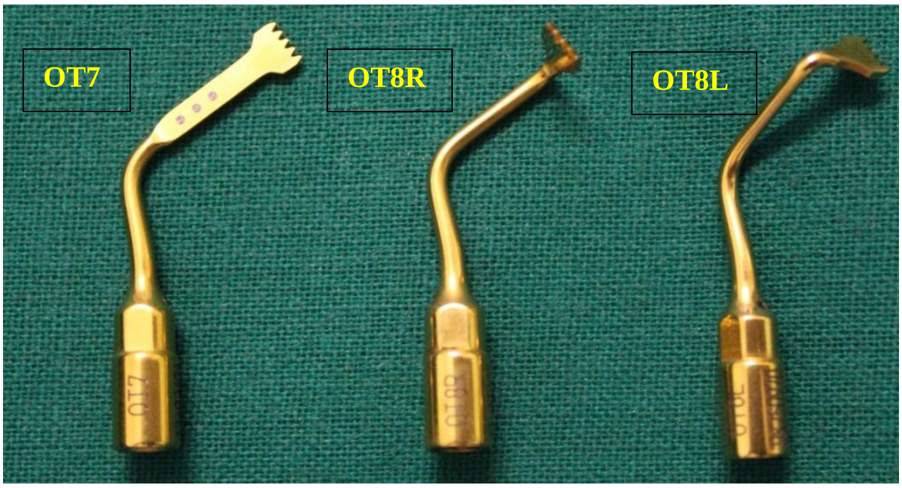


Fig. 3: PIEZOSURGERY KIT

Fig. 4: LEVEL AND MODE

Fig. 5: MICROMOTOR AND HANDPIECE KIT

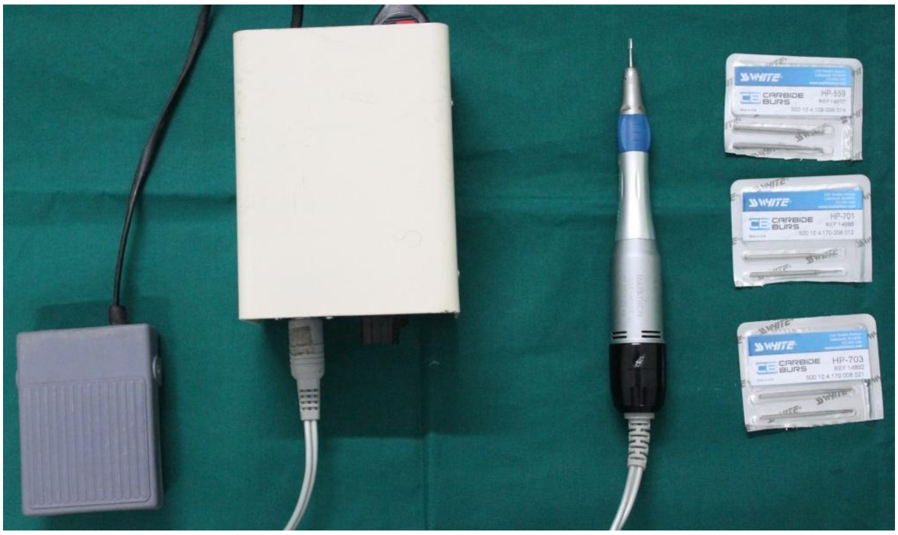


Fig. 6: STRAIGHT HANDPIECE AND BURS

Fig. 7: TOOLS FOR MEASURING SWELLING AND NEUROSENSORY EVALUATION

Results

RESULTS

Out of the twelve patients who underwent orthognathic surgery there were 5 women (42%) and 7 men (58%) with a mean age of 20.66 years and range between 17 – 25 years. Clinical characteristics of all these patients are summarized in table 1. For statistics purpose all the data has been noted in the designed proforma which was then entered in Microsoft excel sheets during the course of study and A Mann-Whitney U test has been used to analyse the data within intergroup and intragroup parameters for comparison between the piezosurgery and conventional rotary drill procedures.

1. Intra-operative parameter:

Blood loss: (Table 2)

Estimation of blood loss during the orthognathic surgery was taken as an intra-operative parameter. The mean blood loss **(MBL)** value during the piezosurgery procedure was estimated as **245.83 ml** with a standard deviation **(SD)** of **56.64,** while the traditional bur procedure led to a **MBL** of **403.75 ml** & **SD** of **63.68**, with a mean difference of **157.92 ml** of blood loss which was statistically significant of ***p*** value **<0.001**. Individually when each jaw was compared, the maxilla in piezosurgery group presented a **MBL** of **122.08 ml** & **SD 59.67** against the **MBL** of **198.75 ml** & **SD 68.79** by the conventional rotary procedure, which was also statistically significant with a ***p*** value of **0.006** and in the mandible, a **MBL** of **123.75 ml** & **SD 39.204** was observed when compared to **MBL** of **205 ml** & **SD 32.613** in the conventional bur osteotomy side, which was again statistically significant with a ***p*** value of **<0.001**. Overall there has been a significant reduction of blood loss in the piezo study group compared to the conventional bur group.

2. Post-operative parameters:

Pain, swelling and neurosensory evaluation have been assessed as post-operative parameters in this study.

Pain: (Table 3 & 4)

Two pain scores, Wong Baker Faces pain rating scale (**WBFPS**) and numeric pain scale (**NPS**) were recorded on the 1st, 3rd and 7th post-operative days. There was no statistically significant difference in the pain rating scales by the patients on the 1st post-operative day but from the **3rd** day onwards, pain subsided earlier in the piezosurgery side (**50%** had no pain) when compared to the conventional bur side (only **15%** had no pain), with a significant ***p*** value of **0.02** (**WBFPS**) and **0.01** (**NPS**) respectively. Pain on the 7th post-operative day subsided more or less equally in both the study groups showing statistically no significant difference between the two groups. This showed that pain started decreasing at an early duration of time in the piezosugery side than in the conventional rotary side and this may be contributed to the decreased injury to the bone and minimal amount of bone removed by piezosurgery.

Swelling: (Table 5)

Post-operatively swelling was also assessed on the pre-operative and on 1st, 3rd, 7th days and 1st month post-operatively. All the post-operative readings were compared to the pre-operative readings in each study group. Results showed that there is no statistically significant difference in the swelling on any of the evaluated post-operative days in both groups. In fact the swelling in both the groups was increased on the 1st to 3rd post-operative days and then gradually kept decreasing which reached near normal by the end of 1st post-operative month.

Nerve impairment: (Table 6,7,8&9)

Post-operative neurosensory evaluation was done on 1st & 7th days and 1st, 3rd & 6th month respectively. Three objective tests (light touch sensation, pin-prick test and static 2-point test) were evaluated on each side individually over the reference points chin, inferior lip and body of the mandible and a subjective evaluation form was given to the patient to note their sensory perception at regular intervals on 1st and 7th post-op days and again on 1st and 3rd months.

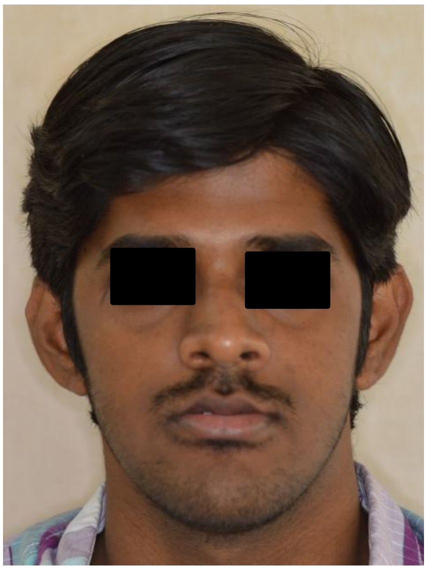
Objective neurosensory evaluation tests when viewed individually showed that there was no statistically significant difference of the sensory perception at the end of 1 week in either of the groups. But at the end of 1 month the ***p*** value has reached a significant value of **0.02** (**static 2-point**) and

0.039 (**pin-prick**) respectively with no significant difference in fine sensation (**light touch**). This showed that the nerve healing was faster in the piezosurgery side than in the conventional bur side. Overall when a cumulative of all the objective tests were evaluated, the results showed that there was a statistically significant improvement in the sensory recovery in the piezosurgery group until 3 months of interval with ***p*** values of **0.043** (**1st day**), **0.046** (**7th day**), **0.049** (**1st month**) and **0.046** (**3rd month**) respectively when compared to the conventional group.

Subjective neurosensory evaluation results showed significant sensory appreciation on the piezosurgery side until 1 month interval with ***p*** values of **0.007** (**1st day**), **0.001** (**7th day**) and **0.005** (**1st month**) respectively. All together this showed that there has been a significant improvement in neurosensory recovery in the piezosurgery side at an earlier duration of time than when compared to the conventional surgery which took atleast 3 months of duration to reach near normal values.

8. Patient's Pre-Op Extra-Oral Photographs

Frontal Profile at Rest



Frontal Profile at Smile

Right Lateral Profile

$3/4^{th}$ Profile

9. Patient's Pre-Op Intra-Oral Photographs

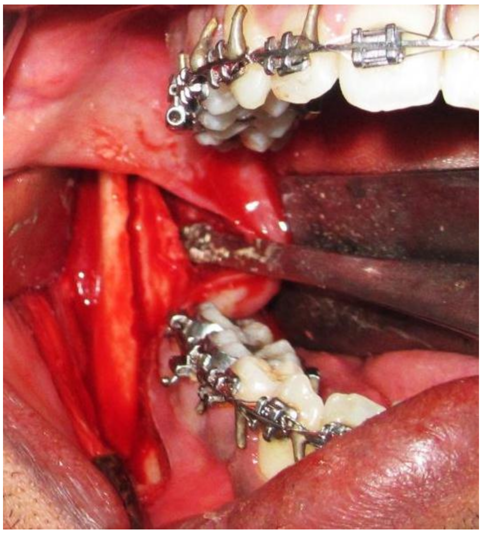
Frontal Occlusal View

Right Lateral Occlusal View

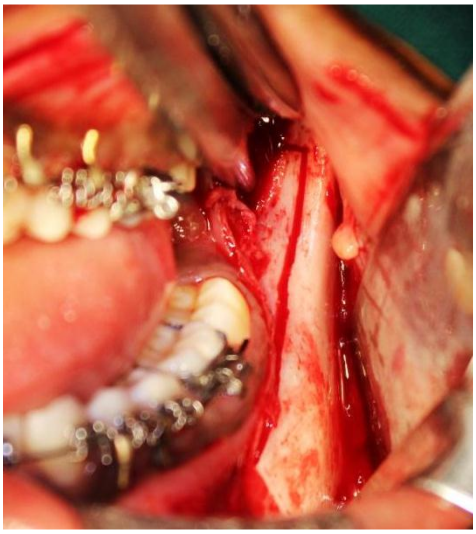
Left Lateral Occlusal View

10. Pre-op Lateral Cephalogram

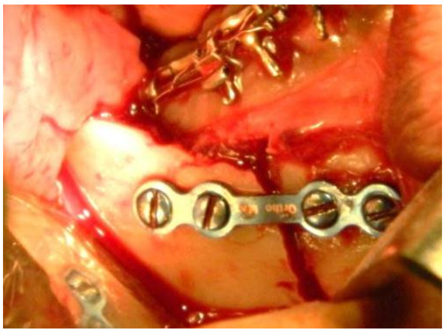
11. Comparison of Intra-Op Photographs of BSSRO



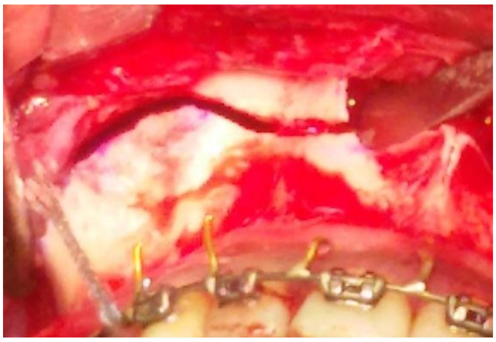
Conventional Bur osteotomy



Piezo-osteotomy

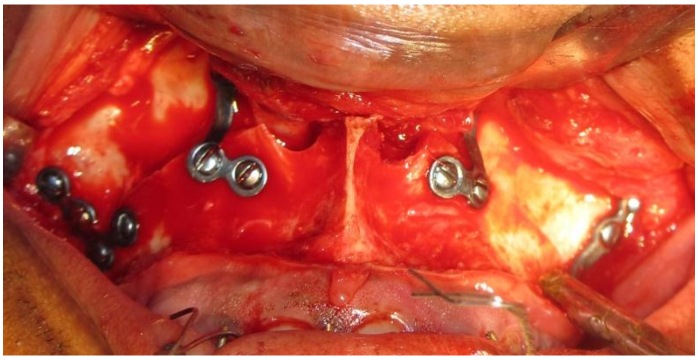


12. Comparison of Intra-Op Photographs of Maxillary Le Fort I Osteotomy



Conventional Bur osteotomy

Piezo-osteotomy



Fixation with L-plates

13. Post-Operative Extra-Oral Photographs

Frontal Profile

Right Lateral Profile

3/4th Profile

14. Post-Operative Intra-Oral Photographs

Frontal occlusal view

Right Lateral Occlusion

Left Lateral Occlusion

15. Post-Operative Lateral Cephalogram

16. Patient's Pre-Op Extra-Oral Photographs

Frontal Profile

Occlusal Cant

Right Lateral Profile

Left Lateral Profile

17. Patient's Pre-Op Intra-Oral Photographs

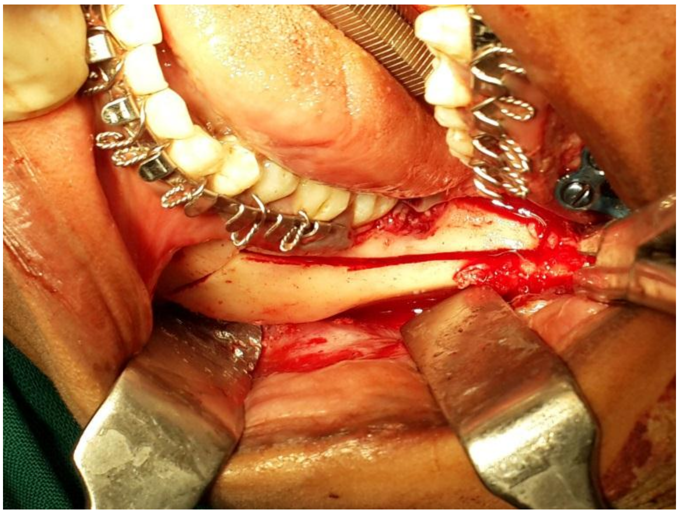
Frontal Occlusal View

Right Lateral Occlusal View

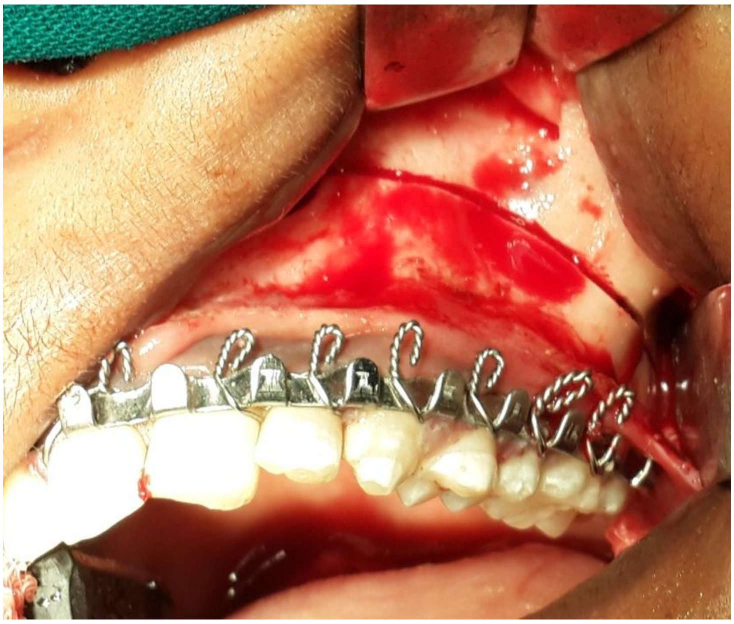
Left Lateral Occlusal View

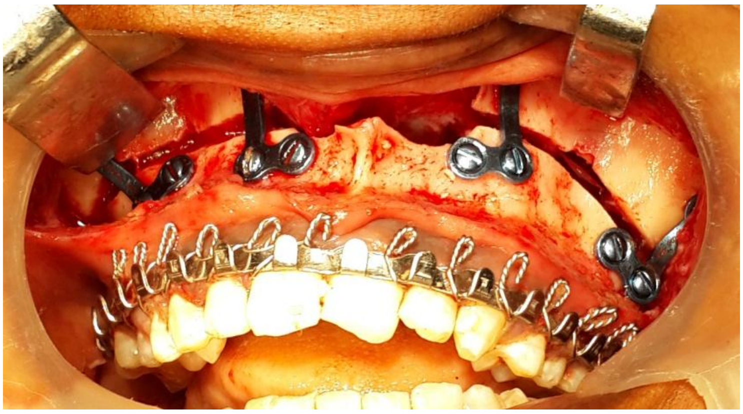
18. Pre-op PA Cephalogram

19. Intra-Op Photographs of Mandible with Piezosurgery



20. Intra-Op Photographs of Maxilla with Piezosurgery





21. Post-Operative Extra-Oral Photographs

Frontal Profile

Right Lateral Profile

Left Lateral Profile

22. Post-Operative Intra-Oral Photographs

Frontal occlusal view

Right Lateral Occlusion

Left Lateral Occlusion

23. Post-Operative PA Cephalogram

Tables and Graphs

Table 1: Clinical characteristics of the twelve patients

Case	Age (year)	Sex	Skeletal deformity
1	22	F	Class I skeletal malocclusion with right side facial asymmetry
2	18	M	Class II skeletal malocclusion
3	22	F	Class II skeletal malocclusion
4	17	F	Class III skeletal malocclusion
5	19	M	Class II skeletal malocclusion
6	22	M	Class III skeletal malocclusion
7	24	M	Class III skeletal malocclusion
8	23	F	Class II skeletal malocclusion
9	21	M	Class III skeletal malocclusion
10	19	M	Class III skeletal malocclusion
11	21	F	Class II skeletal malocclusion
12	20	M	Class II skeletal malocclusion

Table 2: Intra-operative Blood loss in ml.

	Group	N	Mean	Standard Deviation	Mean difference	P-value
Maxilla	Piezosurgery	12	122.08	59.676	-76.667	**.006**
	Conventional	12	198.75	68.792		
Mandible	Piezosurgery	12	123.75	39.204	-81.250	**<0.001**
	Conventional	12	205.00	32.613		
Total	Piezosurgery	12	245.83	56.642	-157.917	**<0.001**
	Conventional	12	403.75	63.680		

Graph 1: COMPARISON OF BLOOD LOSS IN ML

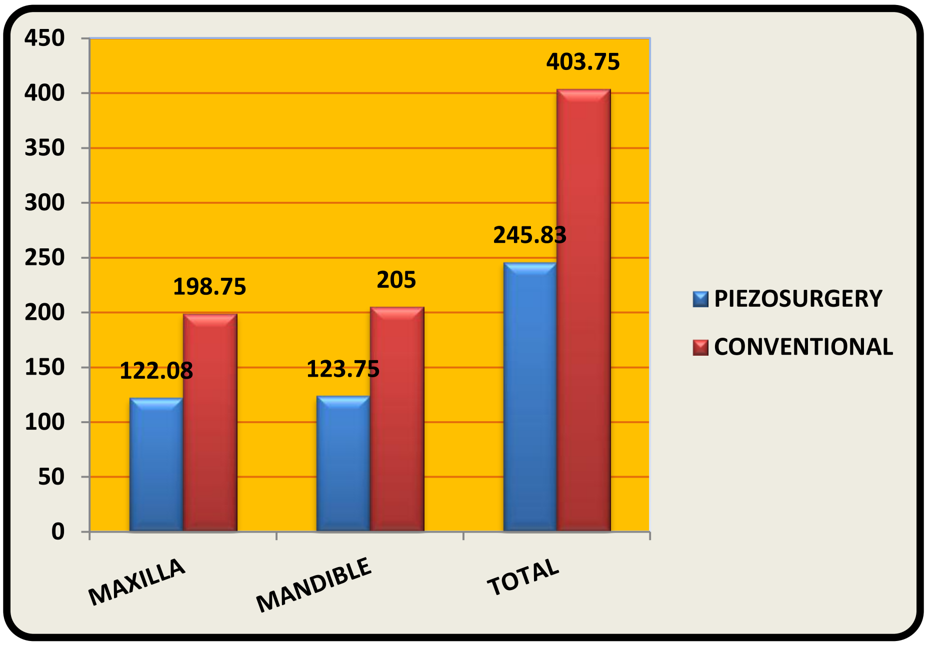


Table 3: Wong Baker Faces pain rating scale

	Group	N	Mean	Standard Deviation	Mean difference	P-value
1st day	Piezosurgery	12	2.33	1.670	-1.667	0.101
	Conventional	12	4.00	2.412		
3rd day	Piezosurgery	12	1.17	1.337	-1.833	**0.028**
	Conventional	12	3.00	2.000		
7th day	Piezosurgery	12	.17	.577	-0.833	0.160
	Conventional	12	1.00	1.348		

Graph 2: COMPARISON OF WONG BAKER FACES PAIN RATING SCALE

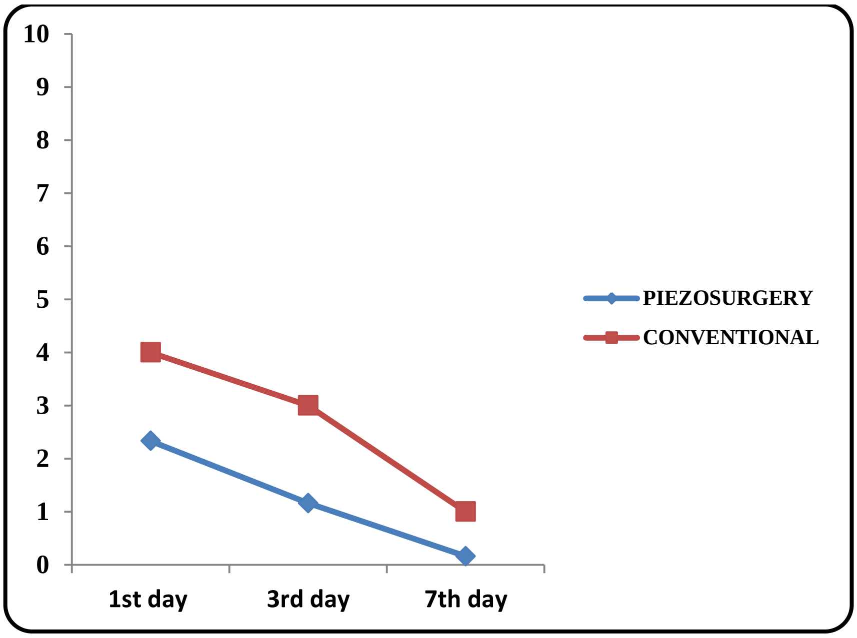


Table 4: Numeric pain scale

	Group	N	Mean	Standard Deviation	Mean difference	P-value
1st day	Piezosurgery	12	2.33	2.462	-2.750	.052
	Conventional	12	5.08	3.579		
3rd day	Piezosurgery	12	.92	1.443	-3.167	.010
	Conventional	12	4.08	3.088		
7th day	Piezosurgery	12	.17	.577	-1.083	.160
	Conventional	12	1.25	1.913		

Graph 3: COMPARISON OF NUMERIC PAIN RATING SCALE

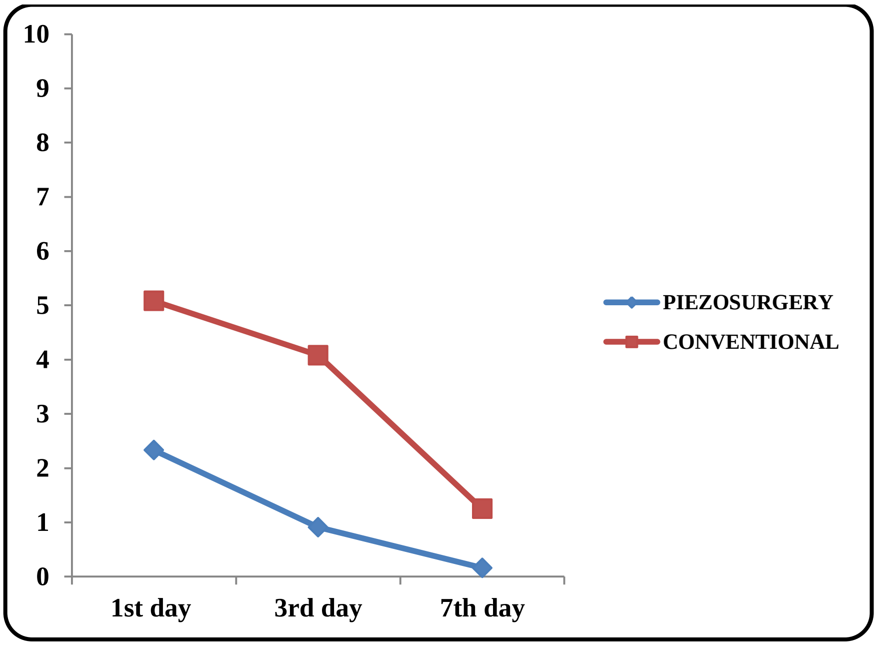


Table 5: Swelling

	Group	N	Mean	Standard Deviation	Mean difference	P-value
Pre –Op swelling	Piezosurgery	12	470.42	25.357	0.000	1.000
	Conventional	12	470.42	25.357		
1st day	Piezosurgery	12	504.17	25.211	-2.000	.932
	Conventional	12	506.17	35.213		
3rd day	Piezosurgery	12	502.08	25.536	-5.000	.843
	Conventional	12	507.08	34.802		
7th day	Piezosurgery	12	482.50	25.159	-16.583	.143
	Conventional	12	499.08	30.258		
1 month	Piezosurgery	12	470.83	24.939	-4.167	.799
	Conventional	12	475.00	27.716		

Graph 4: COMPARISON OF FACIAL SWELLING

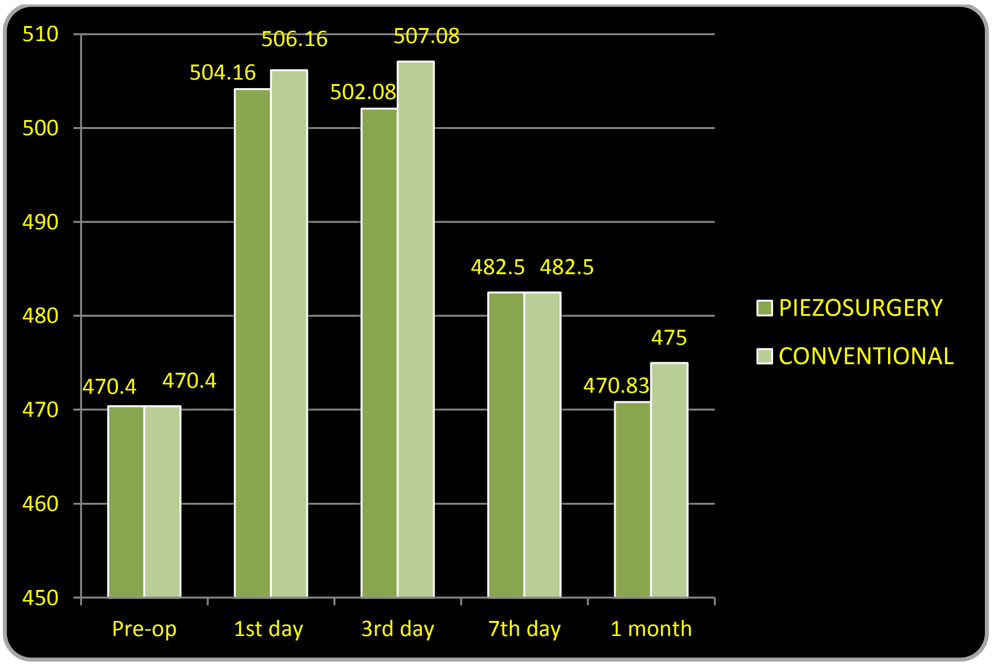


Table 6: Light Touch Sensation

	Group	N	Mean	Standard Deviation	Mean difference	P-value
1st day	Piezosurgery	12	.17	.389	0.083	0.755
	Conventional	12	.08	.289		
7th day	Piezosurgery	12	.33	.492	0.167	0.514
	Conventional	12	.17	.389		
1 month	Piezosurgery	12	.75	.452	0.417	0.089
	Conventional	12	.33	.492		
3 months	Piezosurgery	12	1.00	.000	0.167	0.514
	Conventional	12	.83	.389		
6 months	Piezosurgery	12	1.00	.000	0.083	0.755
	Conventional	12	.92	.289		

Graph 5: COMPARISON OF LIGHT TOUCH SENSATION

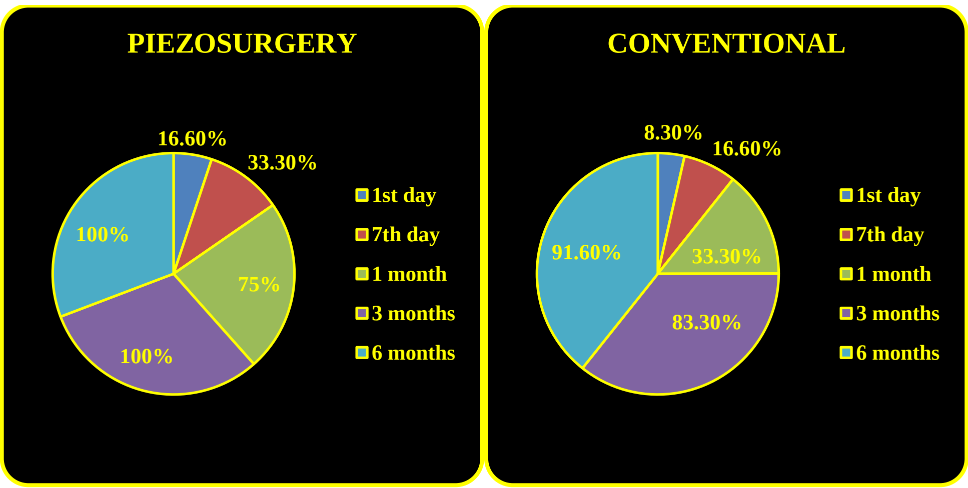


Table 7: Pin-Prick Test

	Group	N	Mean	Standard Deviation	Mean difference	P-value
1st day	Piezosurgery	12	.17	.389	0.083	0.755
	Conventional	12	.08	.289		
7th day	Piezosurgery	12	.42	.515	0.250	0.319
	Conventional	12	.17	.389		
1 month	Piezosurgery	12	.92	.289	0.5	**0.039**
	Conventional	12	.42	.515		
3 months	Piezosurgery	12	1.00	.000	0.083	0.755
	Conventional	12	.92	.289		
6 months	Piezosurgery	12	1.00	.000	0	1.000
	Conventional	12	1.00	.000		

Graph 6: COMPARISON OF PIN-PRICK TEST

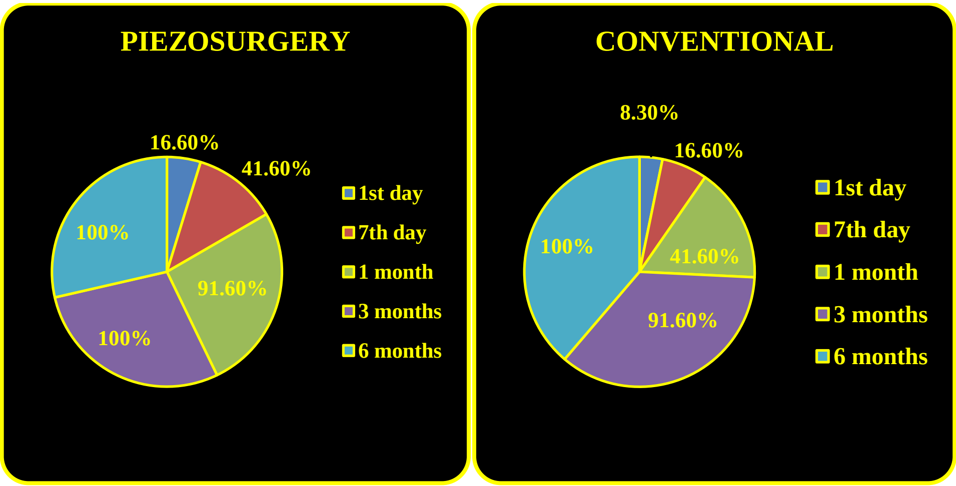


Table 8: Static 2-Point Discrimination Test

	Group	N	Mean	Standard Deviation	Mean difference	P-value
1st day	Piezosurgery	12	1.17	.937	.750	.068
	Conventional	12	.42	.900		
7th day	Piezosurgery	12	1.67	1.073	0,833	.068
	Conventional	12	.83	.937		
1 month	Piezosurgery	12	3.75	.965	1.333	**.002**
	Conventional	12	2.42	.669		
3 months	Piezosurgery	12	4.83	.389	.500	.078
	Conventional	12	4.33	.651		
6 months	Piezosurgery	12	5.00	.000	.250	.514
	Conventional	12	4.75	.622		

Graph 7: COMPARISON OF STATIC 2-POINT DISCRIMINATION TEST

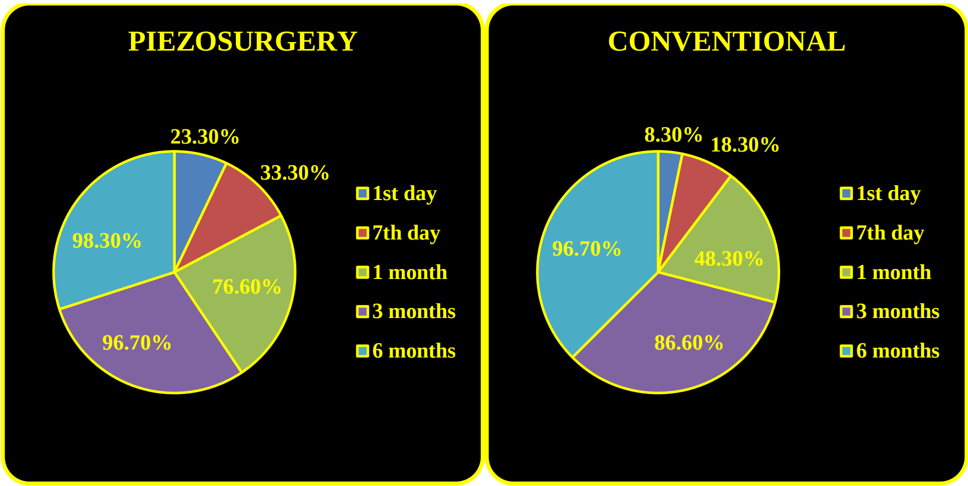


Table 9: Overall Neurosensory Evaluation

	Group	N	Mean	Standard Deviation	Mean difference	P-value
1st day	Piezosurgery	3	18.884	3.853	10.533	**0.043**
	Conventional	3	8.331	0.002		
7th day	Piezosurgery	3	36.108	4.808	18.89	**0.046**
	Conventional	3	17.218	0.966		
1 month	Piezosurgery	3	81.109	9.175	40.01	**0.049**
	Conventional	3	41.108	7.517		
3 months	Piezosurgery	3	98.889	1.925	11.67	**0.046**
	Conventional	3	87.219	4.192		
6 months	Piezosurgery	3	100.000	0.000	3.89	0.121
	Conventional	3	96.109	4.198		

Graph 8: COMPARISON OF OVERALL NEUROSENSORY EVALUATION

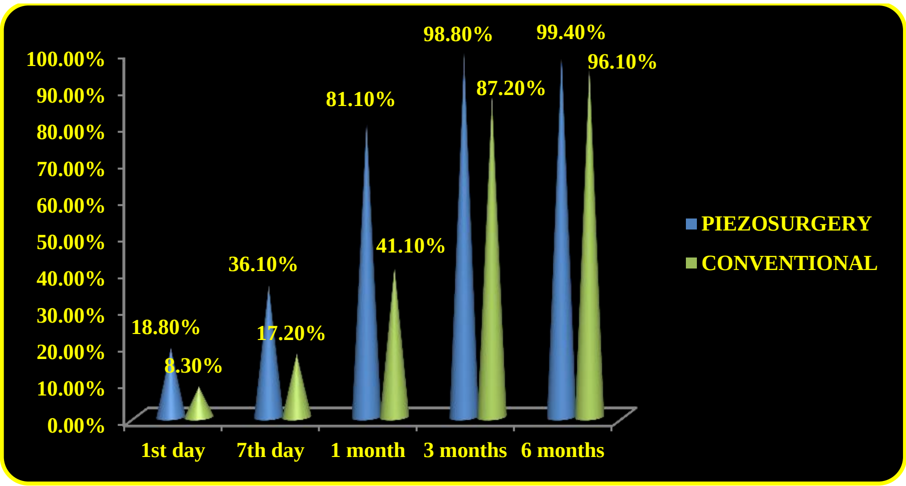
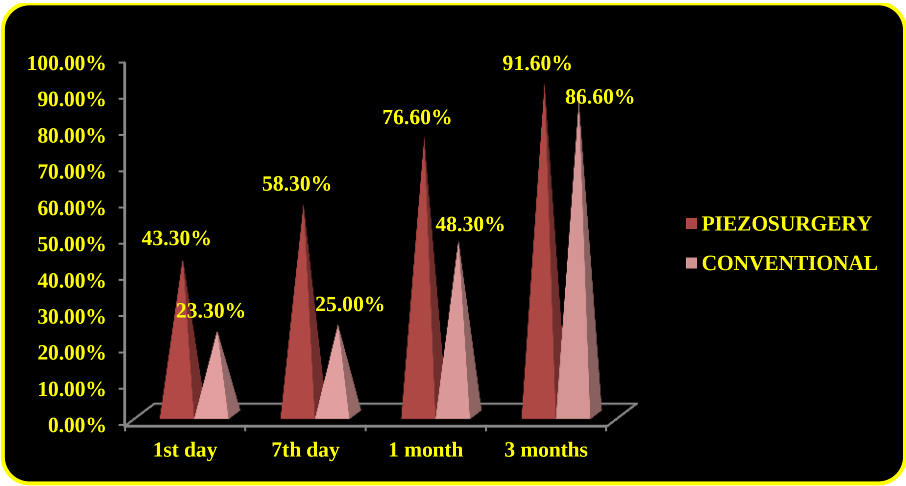


Table 10: Subjective Neurosensory Assessment

	Group	N	Mean	Standard Deviation	Mean difference	P-value
1st day	Piezosurgery	12	43.33	18.749	20.000	**0.007**
	Conventional	12	23.33	11.547		
7th day	Piezosurgery	12	58.33	23.290	33.33	**<0.001**
	Conventional	12	25.00	12.432		
1 month	Piezosurgery	12	76.67	23.868	28.33	**0.005**
	Conventional	12	48.33	18.007		
3 months	Piezosurgery	12	91.67	13.371	5	0.514
	Conventional	12	86.67	17.753		

Graph 9: COMPARISON OF SUBJECTIVE NEUROSENSORY ASSESSMENT



Discussion

DISCUSSION

Piezosurgery is a relatively newer, safer and minimally invasive technique that has been introduced by **T. Vercellotti**[61] in the year 1997 as an alternative to the conventional techniques which are more invasive. It is characterized by piezoelectric ultrasonic vibrations of a frequency range of **24-29 kHz** and works at a controlled speed between **60-200 Hz** which selectively cuts only the mineralized tissues without damaging the adjacent soft tissues, blood vessels and nerves[47] for which a frequency range of above **50kHz** is required. These micrometric vibrations ensure precise cutting and the cavitational[47] phenomenon maintains a blood free site during the surgery.

Based on these advantages, various authors[4,8,10,12,13,14,20,24,35,39,40,53,63] have conducted comparative studies between piezosurgery and the conventional surgical techniques ranging from manual chiseling methods to mechanical tools like rotary drills and saw and mentioned that, piezosurgery causes lesser damage to the adjacent soft tissues, inferior alveolar nerve and the schneiderian membrane, reduces post-operative swelling and pain, decreases intra-operative blood loss, promotes healing at a faster pace with good inter-digitation of the osteotomized segements.

Taking these advantages into consideration, we have conducted this a comparative study and evaluated the effects of piezosurgery over conventional rotary instruments in patients undergoing orthognathic surgery, and obtained the consequent quality of treatment outcomes in orthognathic surgery in terms of blood loss, pain, swelling and nerve impairment.

It has been well documented by Pineiro-Aguillar and his colleagues[49] in their review, that a mean volume of intra-operative bleeding of 436.11 ml was recorded during the conventional orthognathic surgery. And in our study results, we have found a significant reduction in the intra-operative blood loss on an average of about **245.83** ml with piezosurgery when compared to **403.75** ml using rotary instruments with a mean difference of 157.92 ml blood loss (***p* <0.001**). There was also a significant reduction (maxilla ***p*** = **0.006** and mandible ***p*** = **0.001**) in the mean blood loss when the jaws were compared individually.

Similar study was reported by **Kramer FJ et al[33]** who reviewed 1000 conventionally osteotomized Le Fort I patients and reported a total of 6.4% of patients who experienced complications out of which, **1.1%** had extensive hemorrhage requiring blood transfusion (1 patient requiring ligation of the external carotid artery) after bimaxillary corrections. **Telzrow et al[57]** studied the peri-operative complications on 1264 sagittal split osteotomy patients during a 20 year period, and reported a **1.2%** of patients who suffered with hemorrhage. **Landes C.A et al [8, 12]** reported an average blood loss of **541** ml with piezosurgery versus **773** ml with conventional saw and chisel osteotomy while performing orthognathic surgical procedures. **Giuseppe Spinelli et al[24]** has done a split-mouth comparative study between piezosurgery and traditional saw in bimaxillary orthognathic surgery and his results showed a significant reduction in the intra-operative blood loss of **25%** (***p*** = 0.0003). Thus overall in our study and as well as in the documented literature there was a significant reduction in the blood loss in the piezosurgical group when compared to the conventional rotary drills which may be attributed to its oscillation dampening properties of bone leading to more controlled bleeding caused by the cavitational phenomenon of the piezosurgery as explained by **C. Von See et al[8], Landes C.A etal.**[9, 12]

Post-operatively there was no significant difference in pain on the 1st post-op day but it was significantly reduced on the **3rd** day in the piezosurgery side (***p*** = **0.02** & **0.01**). Hence **50%** of the patients experienced no pain on the piezosurgery side from the 3rd day onwards while compared to only **15%** patients with no pain on the conventional rotary side. This showed that the pain started to subside at an early duration of time in the piezosurgery side and can be due to the minimal amount of bone removed and decreased trauma to the bone causing lower oxidative stress expressed by a heat shock protein-70 in the bone by the piezosurgery as reported by **Y. Gulnahar et al.**[63]

A relatively similar study was done by Sabrina **Pappalardo et al**[53] documented a lower visual analog scale score in a randomized clinical study comparing piezosurgery and conventional rotatory surgery in mandibular cyst enucleation. **Manoj Goyal et al.**[40] in his study stated that more patients complained of pain in conventional group and required more analgesics than the piezosurgery group after surgical removal of impacted third molars. **Luigi Piersanti et al**[35] reported a reduced PoSSe scale in a split-mouth, randomized unblinded clinical study in terms of pain, trismus, swelling and surgical time using piezosurgery and conventional rotatory instruments for inferior third molar extractions.

Post-operatively in our study we found that there was no significant difference in the swelling in either of the groups. But other studies in the literature showed that there was a significant reduction in swelling as reported by **Landes C.A et al**[8, 12] and **Giuseppe Spinelli etal.**[24] post-operatively after orthognathic surgery. Many other authors have also reported a reduced amount of swelling post-operatively after performing removal of impacted mandibular 3rd molars using piezosurgery.[40,35,52]

In our study the post-operative objective neuro-sensory testing showed no statistically significant difference of the sensory perception at the end of 1 week in either of the groups. But at the end of 1 month the ***p*** value reached a significant value of **0.02** (**static 2-point**) and **0.039** (**pin-prick**) respectively with no significant difference in fine sensation (**light touch**). A cumulative of neurosensory evaluation results showed that there was a statistically significant improvement in the sensory recovery in the piezosurgery group until 3 months of interval with ***p*** values of **0.043** (**1st day**), **0.046** (**7th day**), **0.049** (**1st month**) and **0.046** (**3rd month**) respectively. Subjective neurosensory evaluation results showed significant sensory appreciation on the piezosurgery side until 1 month interval with ***p*** values of **0.007** (**1st day**), **0.001** (**7th day**) and **0.005** (**1st month**) respectively. This showed that the nerve recovery rate was faster in the piezosurgery side when compared to the conventional drilling side which can be compared to the published literature for mechanical cutting that recovered at nearly 1 year after surgery (**Westermark et al 1999, Gruber et al 2005**).

After reviewing the literature[22] the possible causes of post-bssro facial palsy shows: (a) post-operative hematoma formation at the site of operation causing pressure necrosis of the nerve, (b) direct trauma to the nerve during osteotomy or (c) direct trauma to the nerve while mandibular setback. Similar results have also been reported by **Beziat et al**[7] who described a greater percentage of sensory recovery of inferior lip following piezosurgery.

Geha et al[22] conducted a study in 2004 regarding bilateral sagittal split osteotomy with piezosurgery and reported a complete sensoneural recovery at 2 months was between 75% and 80%. **Ylikontiola L et al,**[64] **Geha et al**[22] **and August M et al**[5] reported >30% of neurosensory disturbances after conventional BSSRO even after 1 year after surgery. **Landes C.A et al,**[8,12] **Stubinger et al,**[56] **Giuseppe Spinelli et al,**[24] **Vercellotti. T**[61] described similar case series with ultrasonic osteotomy and justify that piezosurgery is minimally harmful for the inferior alveolar nerve as a result of the precision offered by the different morphologies of the inserts and the better bleeding control. **Hitoshi Yoshimura et al,**[25] **Kagan Degerliyurt et al,**[30] **M. A.**

Nusrath et al,[36] **Nikolaos Sakkas et al,**[44] have all agreed in emphasizing how the characteristics of the piezoelectric surgery can preserve the integrity of the neurovascular bundle while performing osteotomies close to the inferior alveolar nerve.

Throughout our study clinically there were no complications reported in terms of bone healing. Many studies are still under evolving stage from a histological view, which is focused on the comparison of piezosurgery and traditional tools. **Landes C.A et al,**[8,12] **Chiriac G et al**[11] **and Pooja M Pharne et al**[50] have all done a study on the influence of viability of bone cells within the harvested bone chips and found a significantly large voluminous amount of collected particles with piezosurgery than with conventional rotating devices. **F. Carini et al**[19] in 2014 had done a review paper on piezoelectric surgery on 37 publications in which he has mentioned that the histological studies of bone, showed a reduced bone loss with piezosurgery than compared to the conventional techniques as well as a better healing quality was achieved by reducing patients post-surgery morbidity.

Any alterations in the temperatures are injurious to the viable cells and may cause bony necrosis. In a study done by **Vercellotti T et al,**[60] conventionally treated surgical sites lost bone level by the 14th day while those by piezosurgery gained bone levels. Later, by the end of 56 days there was an evidence of bone loss in the conventionally treated bone in contrast to the bone regain in the piezo group. Therefore piezosurgery favoured better osseous healing and remodeling after surgery when compared to the conventional methods used.

Being different from other surgical osteotomy techniques, piezosurgery requires different surgical skills. Excessive pressure or too much load on the piezosurgical handpiece should be avoided because as the pressure increases the inserts do not vibrate efficiently and the cutting action is reduced leading to inefficient control of bleeding and poor osteotomies. It should only be moved in a back and forth movements continuously with a minimum pressure unlike the other mechanical drills or saws which need a greater pressure while performing the osteotomies and the operator should have a good tactile awareness while performing osteotomies with piezosurgery.[18, 24]

In terms of surgeons comfort, we have reported a higher cutting precision when using piezosurgery with good visibility of the surgical filed. (**R. M. Gruber et al 2005, Alberto Gonzalez-Garcia et al 2007, Guiseppe Spinelli et al 2014).** Also piezosurgery allows a good bony contact or interdigitation after repositioning of the osseous segments and minimized the need for osteofixation.[12]

Thus all in all our study suggests that piezosurgery has a great influence on the precision of bone cutting, it aided in reducing the intra-operative bleeding, reduced pain and neurosensory impairment, promoted bone healing with good inter-digitation between the osteotomized segments, removes the detritius efficiently by its cavitational phenomenon and selective cutting of only the mineralized tissue without damaging the critical anatomic structures and adjacent soft tissues.

Summary and Conclusion

SUMMARY AND CONCLUSION

In this split-mouth prospective study we have compared the effects of piezosurgery osteotomy with those of conventional rotary drill osteotomies in twelve patients who underwent maxillo-mandibular orthognathic surgery in terms of intra-operative blood loss and post-operative pain, swelling and nerve impairment. We found that:

- According to the literature that has been reviewed blood loss has been recorded as one of the most commonly seen complication during a bimaxillary surgery. But with the piezosurgery osteotomy, the intraoperative blood loss has been reduced significantly and a mean difference of 157.92 ml of blood loss has been recorded. This showed that the use of piezosurgery helps in reducing the amount of blood loss which ultimately improved the intra-operative visibility by its dampening effect caused by the cavitational phenomenon.
- Post-operative pain was severe in both the groups on the 1^{st} day after surgery, but it started subsiding by 3^{rd} day on the piezosurgery (50%) side when compared to the conventional drill side (15%) osteotomy. Pain was considerably reduced in both the groups at the end of 1week. This suggests that piezosurgery helped in reducing the amount of bone wastage which ultimately reduced the amount of stress on the bone healing and helped in improving the patients comfort and compliance post-operatively in a shorter duration of time.

- Neurosensory recovery was significantly faster on the piezosurgery side (81.10% at 1 month interval) than when compared to the conventional group (41.10%) which took atleast 3 months of recovery to reach near normal values. This may be attributed to the minimally invasiveness and the ability of the ultrasonic vibrations to just selectively cut the mineralized tissue alone without causing much damage to the adjacent neurovascular bundles and soft tissues which had helped in maintaining the integrity of the critical anatomic structures.
- We have found that there has been no significant difference in the swelling that has been recorded in both the groups. Swelling was at its peak by 3rd post-operative day but it eventually started reducing in both the groups and reached near normal values at the end of 1 month.

In our experience we have observed that piezo-osteotomy appears to be a promising and reliable instrument that provides with several advantages in terms of surgical outcomes as well as patients comfort. It offers precise and selective bony cutting, good margins for easy approximation and inter-digitation of the bone, minimal wastage of the bone without causing any deleterious effects on the adjacent soft tissues and neurovascular bundles.

It can be easily used by the beginners while operating surgeries in the critical anatomic regions. Yet several questions are raised concerning the piezo-osteotomy technique which requires further studies on a larger scale.

And though the amount of time taken, the breakage and cost of the inserts are more, its advantages and efficacy in reducing the complications are far more profitable when compared to any other conventional procedures.

Therefore, we conclude that piezosurgery is a newer and safer innovation that can be used in routine orthognathic surgical procedures that involves osteotomies in close proximity to the critical anatomic structures.

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Annexures

INTRA-OPERATIVE BLOOD LOSS IN ml								
PATIENTS	AGE	SEX	PIEZOSURGERY (LEFT)			CONVENTIONAL ROTARY (RIGHT)		
			MAXILLA	MANDIBLE	TOTAL	MAXILLA	MANDIBLE	TOTAL
1	22	F	250	110	360	350	200	550
2	18	M	90	160	250	160	250	410
3	22	F	80	170	250	140	260	400
4	17	F	100	85	185	200	190	390
5	19	M	140	140	280	200	215	415
6	22	M	150	70	220	195	200	395
7	24	M	70	180	250	160	240	400
8	23	F	60	165	225	145	215	360
9	21	M	130	75	205	250	180	430
10	19	M	145	90	235	200	150	350
11	21	F	200	130	330	285	175	460
12	20	M	50	110	160	100	185	285

PAIN SCORING

	Piezosurgery						Conventional Rotary					
Pts.	WBFPS			NPS			WBFPS			NPS		
	Day 1	Day 3	Day 7	Day 1	Day 3	Day 7	Day 1	Day 3	Day 7	Day 1	Day 3	Day 7
1	2	0	0	1	0	0	6	6	4	9	8	6
2	2	0	0	1	0	0	0	0	0	0	0	0
3	2	0	0	1	0	0	2	2	0	2	2	0
4	2	2	0	3	1	0	4	2	0	7	5	0
5	4	2	0	5	2	0	6	4	2	9	6	3
6	2	0	0	2	0	0	4	4	2	7	7	1
7	0	0	0	0	0	0	2	2	0	1	1	0
8	4	2	0	5	1	0	8	6	2	9	8	2
9	2	2	0	1	1	0	6	4	2	6	6	3
10	2	2	0	1	1	0	2	2	0	1	1	0
11	6	4	2	8	5	2	6	4	0	8	5	0
12	0	0	0	0	0	0	2	0	0	2	0	0

SWELLING

Pts.	Piezosurgery					Conventional Rotary				
	Days					Days				
	Pre-op	1	3	7	1 month	Pre-op	1	3	7	1 month
1	495	515	515	500	495	495	525	515	509	495
2	500	540	535	500	500	500	589	590	565	530
3	450	475	470	452	450	450	470	470	465	450
4	450	460	460	453	450	450	465	470	460	455
5	430	490	485	450	430	430	485	485	475	440
6	450	480	480	460	450	450	470	475	475	450
7	475	505	500	485	475	475	510	510	505	480
8	480	510	510	495	480	480	520	520	510	480
9	490	520	520	505	490	490	510	525	510	490
10	510	545	545	530	510	510	540	540	535	510
11	445	500	495	475	450	445	490	485	485	450
12	470	510	510	485	470	470	500	500	495	470

LIGHT TOUCH SENSATION

Pts.	Piezosurgery (Left)					Conventional Rotary (Right)				
	Days					Days				
	1	7	1 month	3 months	6 months	1	7	1 month	3 months	6 months
1	0	0	1	1	1	0	0	1	1	1
2	0	0	1	1	1	0	0	0	1	1
3	0	0	1	1	1	0	0	0	1	1
4	0	0	0	1	1	0	0	0	1	1
5	1	1	1	1	1	1	1	1	1	1
6	0	0	0	1	1	0	0	0	1	1
7	0	1	1	1	1	0	0	0	1	1
8	0	0	1	1	1	0	1	1	1	1
9	0	0	1	1	1	0	0	0	0	1
10	1	1	1	1	1	0	0	0	0	0
11	0	0	0	1	1	0	0	0	1	1
12	0	1	1	1	1	0	0	1	1	1

PIN-PRICK TEST

Pts.	Piezosurgery (Left)					Conventional Rotary (Right)				
	Days					Days				
	1	7	1 month	3 months	6 months	1	7	1 month	3 months	6 months
1	0	1	1	1	1	0	0	1	1	1
2	0	0	1	1	1	0	0	0	1	1
3	0	0	1	1	1	0	0	0	1	1
4	0	0	1	1	1	0	0	0	1	1
5	1	1	1	1	1	1	1	1	1	1
6	0	1	1	1	1	0	0	1	1	1
7	0	1	1	1	1	0	0	0	1	1
8	0	0	1	1	1	0	0	1	1	1
9	0	0	1	1	1	0	0	0	1	1
10	1	1	1	1	1	0	1	1	1	1
11	0	0	0	1	1	0	0	0	0	1
12	0	0	1	1	1	0	0	0	1	1

STATIC 2-POINT DISCRMINATION TEST

	Piezosurgery (Left)					Conventional Rotary (Right)				
Pts.	Days					Days				
	1	7	1 month	3 months	6 months	1	7	1 month	3 months	6 months
1	2	2	4	5	5	0	1	3	5	5
2	0	2	4	5	5	0	1	2	4	4
3	2	2	5	5	5	0	1	2	4	5
4	1	1	4	5	5	0	0	3	5	5
5	2	3	5	5	5	3	3	3	5	5
6	2	2	4	5	5	0	0	2	4	5
7	2	3	4	5	5	1	1	3	5	5
8	2	3	4	5	5	0	0	3	4	5
9	0	0	2	4	5	1	1	2	4	5
10	1	1	3	5	5	0	0	2	4	5
11	0	0	2	4	5	0	0	1	3	3
12	0	1	4	5	5	0	2	3	5	5

SUBJECTIVE NEUROSENSORY EVALUATION

	Piezosurgery (Left)				Conventional Rotary (Right)			
Pts.	Days				Days			
	1	7	1 month	3 months	1	7	1 month	3 months
1	2	4	4	5	1	1	2	4
2	1	2	4	5	1	1	2	4
3	2	3	4	5	1	1	2	5
4	2	2	3	4	1	1	2	4
5	4	5	5	5	3	3	4	5
6	3	4	5	5	1	1	2	5
7	3	4	5	5	1	2	3	5
8	2	3	3	4	1	1	2	4
9	1	2	3	4	1	1	2	4
10	3	3	5	5	1	1	4	5
11	1	1	1	3	1	1	1	2
12	2	2	4	5	1	1	3	5

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REVIEW BOARD APPROVAL LETTER

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TO WHOM SO EVER IT MAY CONCERN

THE THESIS TOPIC **"EFFICIENCY OF PIEZOELECTRIC VS CONVENTIONAL BUR OSTEOTOMY IN ORTHOGNATHIC SURGERY"** SUBMITTED BY **Dr. G. SHARMISHTA** HAS BEEN APPROVED BY THE INSTITTUTIONAL REVIEW BOARD OF RAGAS DENTAL COLLEGE AND HOSPITAL ON 24TH NOVEMBER 2014.

(Dr.S.RAMACHANDRAN, M.D.S)

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