

**Custom made Intra-Oral Tooth Borne Distraction Device
for Rapid Orthodontic Canine Retraction - A Prospective
Study**

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CERTIFICATE

This is to certify that this dissertation titled “**Custom made Intra-Oral Tooth Borne Distraction Device For Rapid Orthodontic Canine Retraction - A Prospective Study**” is a bonafide record of work done by **Dr. M.P.SANTHOSH KUMAR** under my guidance during his postgraduate study period between 2002-2005.

This Dissertation is submitted to THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY, in Partial fulfillment for the Degree of **Master of Dental Surgery in Branch I – ORAL & MAXILLOFACIAL SURGERY.**

It has not been submitted (partial or full) for the award of any other degree or diploma.

GUIDE IN CHARGE

DR.UMA RAMAN, M.D.S,
Professor and
Head of the Department,
Department of Oral &
Maxillofacial Surgery
Ragas Dental College & Hospital,
Uthandi, Chennai.

DR.S.RAMACHANDRAN, M.D.S,
Principal
Ragas Dental College & Hospital,
Uthandi, Chennai.

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INTRODUCTION

Distraction osteogenesis has gained widespread recognition in orthopedic surgery as an effective means of bone lengthening, deformity correction and filling large diaphyseal defects. Recently distraction osteogenesis has been extensively applied to the craniofacial complex and is becoming a viable treatment option in the correction of craniofacial deformities.^{13,41,48,63,60,69,72,78.}

Initially external devices were used for distraction osteogenesis. Later intra-oral appliances came into existence and has been used for lengthening, widening and augmentation to correct several skeletal problems.^{87,80,63,60,48,45,26,24,13,10,11,4,3.} These intra-oral devices can be tooth-borne,^{51,89,56,57.} bone-borne⁵⁵ or both^{42,41} and has gained popularity as it is much simpler, more patient acceptable. In 1976, Bell and Epker described a rapid palatal expansion technique to increase the maxillary width in patients with transverse deficiency using Haas tooth-borne appliance. Guerrero in 1990, reported osteodistraction of the mandibular symphysis using principles of rapid palatal expansion by a custom-made intraoral Hyrax appliance. Later in 1992 McCarthy was the pioneer to report the lengthening of the human mandible by distraction successfully using a

miniaturized Hoffman device. Since then distraction osteogenesis has undergone various metamorphosis in its design and indications to an extent where it can replace other modalities of reconstruction techniques.

A recent innovative use of distraction osteogenesis technique in the field of orthodontic tooth movement is the application of the principle of distraction to move individual tooth segments rapidly thus reducing orthodontic treatment time. The rate of osteogenesis during tooth retraction limits the tooth movement to a maximum of 1 to 1.5mm per month. Conventional orthodontic mechanics achieve space closure at the rate of 1mm per month.

Canine retraction is a slow process and is heavy on anchorage requirement. It takes 6 to 8 months just to retract the canine into the premolar extraction site. A novel method of reducing the time and the anchorage demands during canine movement is by employing the principles of distraction osteogenesis.^{35,43,68,22,71.}

With the present technique of rapid orthodontic canine retraction through distraction osteogenesis by Reha-kisnici and Haluk-iseri,⁶⁸ the dentoalveolus itself is designed as a bone transport segment for posterior movement. Vertical osteotomies were performed around the root of canine teeth, followed by splitting of spongy bone around it. Therefore the design

of surgical technique itself does not rely on periodontal stretching, which obviates overloading and stress accumulation in this tissue, which was the drawback of the previous attempts of canine distraction through the periodontal ligament. Thus, using distraction osteogenesis technique rapid tooth movement can be achieved.

REVIEW OF LITERATURE

Kole et al [1959]³⁸ developed the predecessor of the rapid canine distraction method. He suggested the use of corticotomy technique to assist in moving teeth, either individually or as a group, with orthodontic mechanics. Eight days after surgery, an orthodontic expansion screw was activated twice (0.5mm) in the first week and once (0.25mm) during subsequent weeks, until the final tooth position was achieved within 8 to 10 weeks and allowed 6 months for bone consolidation using retention appliance.

Michael Block, John Daire [1993]⁵³ used distraction osteogenesis in the dogs for lengthening the mandibles and studied the changes in the inferior alveolar nerve following treatment. Physiological and Ultrastructural examination of the nerve was performed. Jaw-Jerk neurosensory

evaluation was also done. They reported that minimal amount of nerve injury was observed and distraction osteogenesis technique can be applied in dogs.

Michael Block, Dodd Brister [1994]⁵⁰ performed a pilot study on dogs and showed that using distraction osteogenesis principle maxillary advancement can be achieved. After anterior maxillary osteotomy the anterior segment was advanced 10mm. Soft and hard tissue formation resulted in complete healing across the distraction gap. They used a jackscrew appliance attached anteriorly to a heavy wire connecting the orthodontic bands and posteriorly to a cast palatal bar that was screwed into the abutment heads of the two implants.

Adi Rachmiel, Ian T. Jackson [1995]³ performed major midface advancement in sheep by gradual distraction & found out that a greater movement of bone segments is possible with good skeletal stability. Using an external device the midface was advanced 36mms in the nasofrontal area and 43mms in the lateral aspect of the maxilla. After removal of the device 1year follow up was done and stable results were obtained.

Adi Rachmiel, Mark Levy, Dov Laufer [1995]⁴ gave report of cases in which lengthening of human mandible by gradual distraction was carried out using an intra-oral approach for corticotomy with the help of an extra-oral bone lengthening device. In this study two children with hemifacial microsomia underwent unilateral mandibular expansion, and one child with severe mandibular micrognathia underwent bilateral mandibular expansion.

Almeida et al [1995]⁷ demonstrated that the medial points on the palatal rugae were stable during normal growth as well as treatment with headgear or functional appliance.

Altuna, Walker, and Freeman et al [1995]⁹ studied that maxilla could be successfully lengthened by surgical assisted rapid orthopedic movement, using the principles of distraction osteogenesis. Three experimental and three control adolescent cynomolgus primates were used in this study. Anterior supraapical osteotomies of the maxilla with bilateral horizontal and interdental osteotomies were created between the first premolars and the canine; the anterior six tooth dental-osseo segment was completely mobilized in all animals. Beginning 1 week after surgery, a Glen-Ross screw oriented anteroposteriorly was opened a quarter turn every 2 days until the anterior segment was advanced by 4 mm in two animals and 6 mm

in one animal. Animals were killed at 6, 8, and 12 weeks after completion of the maxillary orthopedic advancement. Bone deposition was assessed with computerized tomographic scans and histological examination. The computerized tomographic scans showed bone deposition in the osteotomy sites, which was confirmed by histologic observations. They concluded that this technique demonstrated repair by bone rather than soft connective tissue in the osteotomy sites, this procedure could be a useful method of treating midface retrusion.

Michael Block, Andrew chang [1995]⁵¹ advanced the anterior maxilla of the dog using a tooth-borne distraction device & evaluated that significant dental movement than skeletal movement was achieved & that skeletal fixation may be needed for appliances used to advance the maxilla. The anterior maxillary segment was advanced by 10mms in this study.

Bailey et al (1996)¹² conducted a study with pre-treatment and post-treatment maxillary dental casts of 57 patients and concluded that the medial and lateral points of the third palatal rugae are stable landmarks for the construction of reference planes in the evaluation of tooth movement in a transverse, linear and anteroposterior direction, whether patients are treated with or without extraction.

Martin Chin, Bryan Toth [1996]⁴⁸ described the feasibility & potential advantages of using internal devices for distraction osteogenesis in the management of the Maxillofacial skeletal deficiencies & gave a report of five cases. One patient underwent bilateral LeFort 3 advancement, three patients underwent mandibular ramus lengthening, One patient underwent segmental alveolar reconstruction. They gave the potential benefits of using these internal devices like elimination of skin scarring, increased patient compliance and improved stability of attachment of the device to the bone.

Michael Block, Andrew Chang [1996]⁵² investigated the use of distraction osteogenesis for alveolar ridge augmentation in dog mandibles & concluded that augmentation of alveolar ridge using distraction osteogenesis is feasible. They used implant – supported distraction device to obtain a mean increase in the vertical height of the ridge of around 9mms.

Yoshihiro Sawaki, Hajime Ohkubo [1996]⁸⁹ explained the feasibility of using an intra-oral device and osseointegrated implants for mandibular

lengthening by distraction osteogenesis in dogs & stated that these implants can be used in the maxillofacial skeleton for distraction osteogenesis technique. Five adult dogs were used for this experiment. 10mms of distraction was done in this study. The advantages of this apparatus are: implants can be used for anchorage of a retainer to prevent relapse, distraction osteogenesis can be performed using these osseointegrated implants, patient compliance is improved.

Bell, Harper [1997]¹³ applied distraction osteogenesis to widen the mandible in monkeys and investigated the biological variables that affected the procedure. Midsymphyseal vertical interdental osteotomies were performed and a tooth-borne appliance was used. They concluded that the location of the osteotomy site with an adequate margin of alveolar bone contiguous with the adjacent teeth and intact periodontal ligament, is necessary for the induction of the endosteal progenitor cells. Disproportionate movement between superior and inferior portions of the distracted segments was noted.

Douglas Roth, Arun Gosain [1997]¹⁹ made a study in human and canine cadaver mandibles and stated that quantitative volumetric analysis of CT

scans is an accurate method to measure the amount of bone regenerate formed in patients undergoing distraction osteogenesis of mandible & recorded the mean increase in the bone volume after distraction osteogenesis.

Guerrero, Bell [1997]²⁶ performed gradual osteodistraction following vertical interdental symphyseal osteotomy on ten patients with transverse mandibular deficiency and significant dental crowding and they were followed by subsequent non-extraction decompensating orthodontic treatment. They used either intra-oral tooth borne Hyrax or custom made bone-borne osteo-distractor to gradually widen the mandible and successfully achieved the correction of anterior teeth crowding.

Hasler et al (1997)²⁸ compared the rate of maxillary canine retraction into healed and recent extraction sites, using Gjessing retraction springs. They concluded that the canine on the recent extraction side move faster than that on the healed side, but also tipped some what more. They say that this might be due to the insufficient movement to force ratio of the spring, since the center of resistance of the tooth might be located further apically and bone distal to canine being denser near the apex than the marginal area.

Gulati et al (1998)²⁷ made photocopies of pre-retraction and post-extraction casts on the same machine with 1 to 1 duplication. He dropped perpendiculars from the points on the maxillary permanent molars to the incisive papilla perpendicular reference plane and thus measured anteroposterior movement of maxillary molars

Kourosch Tavakoli, Walsh [1998]³⁹ made a study regarding the role of duration of latency period on mandibular osteodistraction & found out that the change of latency period does not alter the properties of the regenerated bone in mandibular distraction osteogenesis & indeed no latency period may be necessary at all in the craniofacial distraction.

Liou and Huang et al [1998]⁴³ proposed a new concept of “distracting the periodontal ligament” to elicit rapid canine retraction in 3 weeks. They coined the term “Dental Distraction” for this procedure. At the time of first premolar extraction, the interseptal bone distal to the canine was undermined with a bur, grooving vertically inside the extraction socket along the buccal and lingual sides and extending obliquely towards the socket base. Then a tooth-borne, custom-made intra-oral distraction device was placed to retract the canine into the extraction space. Both upper and

lower canines were distracted 6.3 into the extraction space within 3 weeks. New alveolar bone was generated and remodeled rapidly in the mesial periodontal ligament of the canine during and after distraction. It became indistinguishable from the native alveolar bone 3 months after distraction. During the distraction, 73% of the first molar did not move mesially and 27% of them moved mesially less than 0.5mm within 3 weeks. No periodontal defect or endodontic lesion was observed throughout and after distraction. The radiographic examination revealed that apical and lateral surface root resorption of the canines was minimal. They concluded that the periodontal ligament could be distracted to elicit rapid canine retraction without complications.

Steven Cohen, William Boydston [1998]⁷⁸ gave a report of an infant case of distraction osteogenesis of the cranium, orbits and midface. They used a new low-profile buried device for this purpose of monobloc distraction osteogenesis on this nine month old girl of Pfeiffer syndrome. They achieved successful results as the nasopharyngeal airway was enlarged and the need for long time placement of the tracheostomy tube was eliminated.

Edward Seldin, Maria.J.Troulis [1999]²⁰ evaluated the possibility of distraction osteogenesis using a new small buried distractor capable of curvilinear movement while following a fixed trajectory in the minipig mandible . They found out curvilinear distraction in the sagittal plane is possible using this new device. This distractor produced a wedge-shaped distraction gap in conformity with geometric principles.

Jason cope and Samchukov et al (1999)³² evaluated tooth movement through regenerate bone at an early time point during the consolidation phase after bilateral mandibular osteodistraction. Two beagle dogs underwent 10mm of bilateral mandibular lengthening via intraoral distraction osteogenesis between the fourth premolars and first molars. After 1 week of consolidation, retraction of the fourth premolars was initiated, immediately after completing premolar retraction, the dogs were sacrificed and the mandibles were analyzed radiographically, histologically, and by dental cast measurements. Initially, all 4 fourth premolars moved distally with 2 of the 4 touching the first molars at the time of sacrifice. They concluded that it is possible to move teeth through regenerate bone, and it appears that tooth movement can begin within weeks of starting the consolidation period.

Jason Cope, Mikhail Samchukov [1999]³³ reviewed the historic development and biologic foundation of mandibular distraction osteogenesis and evaluated the current mandibular distraction devices both intra and extra oral types, with their clinical applications and predicted the future evolution of mandibular osteodistraction technique. It was concluded that the application of osteodistraction offers novel solutions for surgical – orthodontic management of developmental anomalies of the craniofacial skeleton.

Maria Troulis, David Perrott [1999]⁴⁵ conducted a study & found out that through endoscopic approach, exposure and osteotomy of the mandible with placement, fixation and activation of a semi-buried distraction device is feasible. Sixteen cadaver and two live anesthetized pigs were used in this study. Access to the mandible was gained through submandibular incisions which was used for a working port and a visualization port.

Mommaerts [1999]⁵⁴, presented a bone-borne distraction device for transpalatal distraction to achieve maxillary expansion. He stated the disadvantages of the use of tooth-borne devices such as loss of anchorage, skeletal relapse during and after the expansion period, cortical

fenestration and buccal root resorption and stated that the bone borne distractor can be applied successfully in cases requiring transverse maxillary expansion.

Niederhagen, Braumann [1999]⁵⁶ conducted a study in pigs & described that lengthening or widening of the mandible can be achieved using a tooth-borne distraction device instead of bone-borne devices and found out that no detrimental effects at the roots or in the periodontium of the adjacent teeth were seen.

Padwa, Kearns [1999]⁶⁰ described the application of the semi-buried distractor to simultaneously lengthen the mandible and the maxilla & level canted occlusal plane in three cases. Also they reviewed the indications for bimaxillary distraction including its advantages, disadvantages and limitations. Two patients of hemifacial microsomia and one patient of trachear collin's syndrome underwent distraction in this research.

Ploder, Mayr, [1999]⁶⁶ used a newly designed, fully implantable electromechanical device for mandibular lengthening in sheeps. After osteotomy, the device was screw fixed to the mandible, and the power and

the control unit was inserted subcutaneously in the neck region and distraction was achieved. Progression to human clinical applications is awaited.

Reha Kisnici, Stephen and Epker et al (1999)⁶⁹ reported the first case of distraction osteogenesis to widen the mandible with the use of a tooth-borne appliance. In this report, a patient with Silver Russell syndrome and severe mandibular hypoplasia was treated by means of distraction osteogenesis of the midsymphysis to widen the mandible in concert with sagittal-ramus osteotomies to lengthen the mandible so that the severe crowding could be treated with nonextraction orthodontics. The authors concluded that this treatment created significantly increased arch length in the mandible, which was necessary to facilitate the patient's orthodontic treatment and this approach appears to have merits for consideration in similar patients with deficient lower jaws and moderate to severe arch-length discrepancies.

Steven smith, Rohit sachdeva and Jason cope et al (1999)⁷⁹ evaluated the regenerate bone produced during osteodistraction of the dog mandible at three different consolidation times using quantitative computed

tomography. Twelve skeletally mature male beagle dogs were equally separated into three experimental groups. Each dog underwent 10 mm of bilateral distraction osteogenesis to lengthen the mandible. After the distraction period, the bone was allowed to consolidate for 4, 6, or 8 weeks, at which time the animals were sacrificed and the mandibles harvested for computed tomographic imaging. They concluded that a significantly lower mean bone density of the regenerate in the 4 week group when compared with either the 6 or 8 week group. There was no significant difference, however, in mean bone density between the 6 and 8week group.

Suzanne U.McCormick Ronald D.Mizrahi [1999]⁸⁰ used a submerged intra-oral device for distracting the mandible & gave reports of three cases of hemifacial microsomia treated with that. They used a submerged intra-oral Vazquez-dinner distraction device which was applied to the bone through an intra oral approach. All patients tolerated the procedure well and favourable results were achieved.

Ulrich Meyer.Thomas Meyer [1999]⁸⁵ studied on rabbit models to evaluate the expression rate of the two osteogenic marker proteins osteocalcin & osteonectin and found out that hyperphysiological strains

reduced expression rate of the osteocalcin & osteonectin with a significant loss of the crystal formation suggesting a functional role of both proteins related to mechanical loading.

Ulrich Meyer, Ulrich Joos [1999]⁸⁶ studied the various factors influencing bone remodelling in distraction osteogenesis & concluded that gradual distraction of bone in physiologic magnitudes at higher frequencies seems to be desirable for a bony differentiation & may help to improve clinical applications.

Ulrich Meyer. Thomas Meyer [1999]⁸⁴ made a study on rabbits regarding factors affecting distraction osteogenesis and concluded that magnitude and not frequency of mechanical loading controls the differentiation of the bone cells & the subsequent formation of the bone tissue.

William Bell, Mikhail Samchukov [1999]⁸⁷ did simultaneous widening and bilateral lengthening of Baboon mandibles using a miniaturized intra-oral bone –borne distraction device and found that active histogenesis & bone formation occurred in the distraction gap and showed successful results. They concluded that this appliance can be used to widen and lengthen the

mandible. The orientation of the mandibular distractors must be parallel to the common vector of distraction, which should be parallel to the maxillary occlusal plane and the formation of a bone regenerate in the alveolar region depends on the presence of an adequate bone interface on either side of the distraction gap.

Ellen Wen-Ching Ko, Alvaro Figveroa [2000]²¹ conducted a study to evaluate the profile changes after maxillary advancement by distraction osteogenesis using rigid external distraction device & found out that improved facial balance and esthetics occurred as the nasal projection increased normalising the naso-labial angle and making the upper lip more prominent.

Eric Liou, Alvaro Figueroa and John Polley et al [2000]²² hypothesized that a tooth can be moved into the fibrous new bone created by the distraction process at a rapid rate. Four mature beagle dogs were used and an edentulous space was created in 2 weeks by using a bone-borne intraoral distraction device on each side of the mandibular body between the third and fourth premolars. Calibrated elastic threads with 50 g of orthodontic force were applied to move the fourth premolar into the

edentulous space for 5 weeks. On one side, the tooth was moved simultaneously with distraction; and on the opposite side, it was initiated immediately after the cessation of distraction. The fourth premolars were moved 1.2 mm per week. The authors indicated that the best time to initiate tooth movement was immediately after the end of distraction. With this approach, most of the periodontal support was preserved after orthodontic tooth movement. In contrast, moderate to severe alveolar bone loss was noted in the fourth premolars moved simultaneously with distraction.

Hisako Hikiji, Tsyoshi Takato [2000]²⁹ presented a study on white rabbits in which they tried to create neo-condyle and did it successfully using internal devices following the principle of transport disc distraction osteogenesis.

Jason cope and Samchukov et al [2000]³⁴ evaluated the newly formed bone during the consolidation period of mandibular osteodistraction using quantitative histology. Seventeen skeletally mature male beagle dogs underwent 10mm of bilateral mandibular lengthening. After distraction, the regenerates were allowed to consolidate for 0, 2, 4, 6, or 8 weeks, at which time the animals were sacrificed and tissues harvested for standard

histologic and histomorphometric analyses. Result showed mineralization began at the host bone margins by the end of distraction period, followed by a progressive increase in trabecular bone with a concomitant decrease in the amount of fibrous tissue. Between 4 to 6 weeks of consolidation, 3 types of relatively mature distraction regenerates were evident. The mineral apposition rate gradually increased from the end of distraction to the fourth week of consolidation, at which time it remained constant until sometime before the eighth week, where it tapered off slightly as remodeling increased

Keles et al [2000]³⁷ used wire markers for lateral cephalometric analysis of tooth movement and determining the amount of tipping of maxillary molars during distalization with the intraoral bodily molar distalization

Lindsey Douglas, Burton Douglass [2000]⁴² made a study on baboons and found out that it is feasible to use an intra-oral tooth & bone-borne distraction device to distract mandibles by distraction osteogenesis principles.

Lindsey Douglas, Burton Douglass [2000]⁴¹ used an intra-oral tooth & bone borne distraction device for treating a patient with severe

micrognathia [of mandible] secondary to TMJ ankylosis and obtained stable results. They used a pin-in-tube or PIT device, which is simple to apply and requires only an intra-oral incision.

Maria Troulis, Julie Glowacki [2000]⁴⁴ used a porcine animal model & performed mandibular distraction osteogenesis to define the relationship between rate, latency, gap size, duration of fixation and concluded that stability was more in the gap distracted by 1mm per day. They also stated that mandibular lengthening was successfully performed without latency period and when rate was 1mm per day.

Marinho and Cesar Guerrero et al (2000)⁴⁷ evaluated the effects of mandibular symphyseal distraction osteogenesis using a tooth-borne expansion device. The sample included 20 nonsyndromic patients between 13.5 years and 37.3 years of age. Predistracted (1.5 months before surgery), postdistracted (1 month after surgery), and long-term follow-up (1.3 year after surgery) records included posteroanterior, lateral, and panoramic radiographs and models. Postdistracted radiographic evaluation showed that symphyseal distraction osteogenesis produced insignificant increases in the bicondylar, bigonion, and biantegonion widths; intermolar

and, especially, intercanine widths increased significantly and a distraction gap was observed in the symphyseal region. The movement of teeth into the distraction regenerate and concomitant orthodontic treatment resolved dental crowding. Follow-up radiographs showed transverse skeletal stability of the distraction procedure. They concluded that mandibular symphyseal distraction osteogenesis increased mandibular arch width and corrected dental crowding, with a potential for disproportionate distraction patterns and proclination of the mandibular incisors

Niederhagen, Braumann [2000]⁵⁷ used an intra-oral tooth –borne distraction device for widening the mandible to avoid the use of an extra-oral appliance & they reported no detrimental effects on healthy anchoring teeth. They also stated the advantages of intra-oral distraction devices over extra-oral distraction devices.

Peter Kebler, J. Wiltfang [2000]⁶² compared the effects of continuous and discontinuous bone distraction in mini-pigs using an intra-oral microhydraulic osteodistractor and tested the efficiency of the new device.

Selcuk Basa, Evren Uner [2000]⁷² gave a report of a case who underwent distraction osteogenesis of the mandible using a bi-directional extra-oral

distraction device for the reconstruction of a large defect created after tumour resection

Toshiyuki Hagiwara, William Bell [2000]⁸² studied the effects of electrical stimulation during mandibular lengthening by distraction osteogenesis and found out that electrical stimulation promotes new bone formation in the early retention period in the rabbit model

Albino Triaca, Michele Antonini [2001]⁶ used a technique in which a hinged bone plate was used for distracting the mandibular anterior alveolar process for the purpose of correcting anterior crowding & for decompensation of the dentition in class 3 cases.

Al Ruhaimi [2001]⁸ studied on rabbit mandibles regarding the outcome of different distraction rates & found out that the distraction rate of 1mm once a day produced the best osteogenesis and stated that a short period of fixation of a distraction should be achieved by methods other than rapid distraction.

Ayoub and Richardson [2001]¹⁰ have invented a new automatic distractor to produce microincremental distraction and stated that this device worked in animals and further modification of the device is necessary to be applied in the humans. The device was placed intra-orally and had two units: an

implantable component that is applied directly on the bone, and an external component that is distant from the surgical site.

Ayoub and Richardson [2001]¹¹ used a newly developed automatic microincremental distraction device for reconstructing segmental defects in the sheep mandibles and found out that microincremental distraction generated a metabolically active environment resulting from tension at one end and compression at the other end. The device had an implantable component and an external component. Activation of the device is automatic, its effect is continuous during the course of distraction. They stated that this device requires only a minimum level of cooperation by patients which may make it useful for children and handicapped patients.

Claudia and Mommaerts et al [2001]¹⁵ investigated the hypothesis that by changing 2 parameter of standard protocol i.e., separating the pterygomaxillary disjunction and placement of the Transpalatal Distractor on the palate at the level of the first molars resulted in more parallel expansion of the maxillary segments. The transpalatal distractor (TPD)

allows for maxillary expansion according to the concepts of distraction osteogenesis. Twenty consecutive patients were included in a prospective way, and their predistracted and postdistracted models were electronically analyzed. They concluded that pterygomaxillary disjunction changes the center of resistance locating it more posteriorly in relation to the site of force application, and the fulcrum was anteriorly situated which resulted in parallel expansion of maxillary segment

Cope and Samchukov [2001]¹⁷ evaluated the mineralization dynamics of regenerate bone during osteodistracted by plain film radiography, digital subtraction radiography in dogs & devised a classification system based on length, width & density of the mineralizing regenerate as well as the presence or absence of an interzone.

Hoggan and Sadowsky et al (2001)³⁰ in their study on 33 patients treated with first premolar extraction concluded that the rugae landmarks could be used as reliably as cephalometric superimposition to assess anteroposterior molar movements. They suggested that the medial end of the third palatal rugae is a suitable reference point for the assessment of molar and incisor movement.

Jacques Buis, Paul Rousseau [2001]³¹ applied distraction osteogenesis technique in grafted bones using endosseous implants to achieve desirable bone and soft tissue levels in the cleft alveolar ridges thereby enhancing for an ideal prosthetic rehabilitation.

Kai Olaf Henkel, Lian Ma [2001]³⁶ made a study on pigs and later on humans in which they used guided distraction osteogenesis technique for regenerating bone in the cleft alveolar defects by transport disc distraction osteogenesis principle. They used a new horizontal segment distractor.

Mommaerts [2001]⁵⁵ used a bone anchored intra-oral distraction device for transmandibular distraction across a median symphyseal osteotomy. The advantages of this appliance included limited surgical exposure, good skeletal anchorage, and expansion along the arch segment together with proportional and differential widening in the frontal plane

Pascal Pinto, Maurice Mommaerts [2001]⁶¹ analyzed the immediate post expansion positional changes of the maxillary halves resulting from the use

of the transpalatal distractor and found that expansion at the canine levels was greater than at the molar levels.

Peter Kebler, J.Wiltfang [2001]⁶² gave a report of four cases with midfacial microsomia treated by high lefort 1 osteotomies with distraction osteogenesis with submucosal intra-oral distraction device. They stated the advantages of the device used in this technique. Delaire masks were used to stabilize the surgical result after removal of the distractor.

Pilar Rubio Bueno, Esther Villa [2001]⁶⁴ gave an algorithmic table for diagnosis and treatment planning for distraction osteogenesis in mandibular hypoplasia cases and stated that when an additional maxillary deformity is present mandibular distraction is to be performed first and a maxillary procedure will be necessary later.

Stephen Yen, John Gross [2001]⁷⁶ used the dentoalveolar distraction osteogenesis principle for closure of the anterior alveolar cleft defect using posterior segment as the transport bone disc. The distraction device consisted of bone screws, orthodontic brackets, spring, bands, arch wires, that were custom made.

Ulrich Meyer, T. Meyer [2001]⁸³ studied the influence of mechanical loading on bone healing in distraction osteogenesis on rabbit models and showed that the magnitude of the mechanical strain functions as main regulator of bone cell proliferation, differentiation and matrix synthesis. They also suggested that callus formation following tension stress has the potential to cause systemic effects, that may be in part controlled and mediated by cytokines.

Wiltfang and Kebler [2001]⁸⁸ studied the effects of continuous and intermittent bone distraction using a microhydraulic cylinder in minipigs and concluded that continuous bone distraction accelerated the bone healing. They concluded that in continuous bone distraction a smaller amount of pressure is sufficient and bony regeneration is accelerated which may reduce the fixation period.

Gaggi, Schultes [2002]²⁴ have used an implant for distracting alveolar bone [which is deficient] immediately after extraction of the tooth. After successful distraction and bone healing the implant was used to fit the prosthesis. Seven patients with severe periodontitis were treated in this

study. This method is said to be time sparing as the healing period after extraction is avoided.

Norimichi Nakamoto and Hiroshi Nagasaka et al (2002)⁵⁸ verified the influence of tooth movement on tooth roots and periodontal tissues when teeth were moved into mature, well organized, and mineralized bone created after distraction osteogenesis compared with immature, fibrous, and less-mineralized bone. Six 15-month-old male beagles dogs underwent 10mm of bilateral mandibular distraction osteogenesis. After 2-week (group 1) and 12-week (group 2) consolidation, third premolars were moved into the regenerate bone with 100grams of orthodontic force for 12 weeks. Simultaneously, second premolars were also moved distally as controls. Result showed that in group 1 considerable root resorption extending into the dentin and the thickness of the dentin became approximately half that of the compression side. In-group 2, root resorption on the compression side reached the dentin, but the root resorption was less than in group 1. The authors concluded that heavy and early orthodontic tooth movements are not recommended when teeth are moved through regenerated bone created by distraction osteogenesis

Reha Kisnisci and Haluk Iseri et al (2002)⁶⁸ presented a technique of “rapid orthodontic canine retraction”, to reduce the overall orthodontic treatment time by means of dentoalveolar distraction osteogenesis. The dentoalveolar segment is designed as “bone transport segment” for posterior movement. Eleven patients undergoing orthodontic treatment with bilateral first premolar extractions and subsequent bilateral canine tooth distalization underwent osteotomy around the canine tooth. The first premolar was extracted, and the buccal bone was carefully removed. After wound closure, a special orthopedic device was mounted and cemented to the first molar and canine teeth. Distraction was started the same day at the rate of 0.4mm twice a day and continued until canine tooth moved posteriorly and made contact with the second premolar in 8 to 12 days. The distraction rate and the device were well tolerated by all patients. The device was then removed and orthodontic therapy was continued with fixed appliances. Result suggests there was no anchorage loss in the second premolar and first molar teeth. Root resorption, dental ankylosis were not detected. No discoloration or radiographic evidence of loss of tooth vitality was noted. They concluded that the concept of distraction osteogenesis for rapid orthodontic tooth movement is promising and feasible.

Shaw, Mandall [2002]⁷³ proposed a prospective registry, to hasten critical appraisal of the distraction osteogenesis.

Stanley Braun and Alexandre et al (2002)⁷⁵ determined the true nature of condylar displacements associated with mandibular symphyseal distraction osteogenesis. Earlier investigators have assumed that each mandibular half rotated about a point near the center of each condyle as viewed on a submental radiograph. Study included 12- patient sample, 10 with tooth-borne symphyseal distraction and 2 with bone-borne symphyseal distraction. They concluded that that each condyle was laterally displaced in direct relationship to the amount of symphyseal distraction. The rigidity of the distraction appliances and their attachments and the inability of the soft tissues and muscular attachments to cause the mandible to undergo compound bending require this to be the cause. Temporomandibular joints appear to be able to accommodate the lateral displacements because symptoms were not introduced, or, if present before therapy, distraction did not exacerbate them

Stephen Warren, Pierre Bouletreau [2002]⁷⁷ described the molecular mechanisms which governs the formation of new bone in distraction

osteogenesis. They also characterize and discuss regarding the extracellular matrix proteins, cytokines and their regulations during distraction osteogenesis.

Dolanmaz and Ali Ihya et al (2003)¹⁸ evaluated the usage of dento-osseous transport distraction osteogenesis in the treatment of cleft alveolus. The procedure was carried out on eight patients, 3 with bilateral alveolar clefts and two with unilateral alveolar clefts. A custom made tooth-borne distractor was used. Result suggests that the average amount of distraction was eight mm (range 5-11.5mm); average amount of distal movement of the anchorage teeth was 0.8mm(range, 0-2mm), average amount of inclination changes of the transport segments and anchorage teeth was 7.6° (range, 2-17.5°) and 3.3° (range, 0-9°) respectively. They concluded that this method form repairing small or large alveolar cleft is a simple, cost-effective, and useful treatment option.

Gero Kinzinger and Siegfried et al (2003)²⁵ tested whether, after a shortened consolidation phase, orthodontic fine adjustment of the tooth-supporting osteotomy segment could be achieved by applying the “floating bone concept”. They performed a segmental osteotomy with vertical callus

distraction of the ankylosed tooth, using the floating bone concept, and at the same time, 3-dimensional alignment of the tooth-supporting segment using multiband apparatus and appropriate biomechanics followed by a rigid continuous archwire induces relatively fast stabilization of the tooth-supporting segment for immobilization of the callus. They concluded that floating bone concept achieved 3 dimensional alignment of ankylosed tooth, allowing tooth movement into the therapeutically desired position

John. Bilodeau [2003]³⁵ used an intra-oral distraction device successfully to retract permanent canines on a patient and said that surgically assisted dental distraction is a feasible technique for achieving faster tooth movement to reduce the overall orthodontic treatment time. He also stated the indications and advantages of this new technique over the routine orthodontic treatment used to retract the canines.

Maria Troulis, Leonard Kaban [2003]⁴⁶ studied the efficacy of ultrasound for evaluation of bone formation in the mandibular distraction wound. They stated that ultrasound is a useful and accurate method to evaluate bone fill in mandibular distraction wounds in patients. The features like minimal expense, lack of metal artefact, lack of radiation exposure, and lack of the

need for sedation of uncooperative young patients makes ultrasound a powerful adjuvant tool for assessment of bone healing and may decrease the number of serial radiographs required.

Tae and Gong et al (2003)⁸¹ reported a case of dentoalveolar distraction in a repaired unilateral alveolar cleft patient using a tooth-borne distractor. Horizontal osteotomy was made 2mm above the canine and first premolar apex and vertical osteotomy was made mesial to canine and distal to first premolar to close the cleft by a forward transport of bone using a segment from canine and premolar teeth. A tooth borne device was placed on canine and first molar and the distractor was activated until the segment mesialized and reduced the alveolar cleft. Result showed canine tipping forward and the premolar showed mesial in rotation. After a consolidation period of two weeks, the first molar was moved into the newly created bone-regenerated area. They concluded transport distraction osteogenesis would reduce or eliminate the need for a secondary bone graft to the cleft alveolus in cleft patients and help prevent dentoalveolar defects by approximating the native alveolar bone and gingiva.

Abel Garcia Garcia, Manuel Somoza Martin [2004]¹ suggested a classification of alveolar ridge post-distraction as a useful basis for

decision making regarding implantation following ridge augmentation by distraction osteogenesis. Twelve patients underwent alveolar ridge distractions before implant placement. Four morphologic categories were identified and categorized.

Abel Garcia Garcia, Manuel Somoza Martin [2004]² recommended a palatal approach and intra-osseous distractors for alveolar distraction in the upper jaw to rectify insufficient alveolar rim height. Two cases were treated and in both the cases the height of the alveolar rim was successfully increased by 8mms. Transport disc type distraction osteogenesis was used and later implants were placed.

Alan S. Herford [2004]⁵ gave report of five cases who underwent reconstruction of segmental mandibular defects using a reconstruction plate-guided transport distraction osteogenesis segment and the distraction device allowed for ultimate vector control by intimately following a carefully adapted plate. He stated that the advantage of this technique is that it used a reconstruction plate that is routinely placed to bridge mandibular continuity defects.

Faruk Ayhan and Hasan et al (2004)²³ evaluated the biomechanical effects of mandibular midline distraction osteogenesis on the mandibular complex by using a 3 dimensional finite element model, whose construction was based on computer tomography scans of the mandible of 22-year old man. The distraction was performed on the middle intersection point of the vertical and horizontal planes on the mandibular symphysis. The result indicated the mandible was separated almost in parallel manner superioanteriorly. Anteroposteior evaluation demonstrated that the greatest widening was achieved at the symphyseal region, and the widening gradually decreased from anterior to posterior and this resulted in minimal disturbance of the condyle region. The authors suggested that these findings stress the importance of the design and location of the distractor in treating transverse deficiencies. A tooth-borne or borne-borne distractor placed on the mandibular anterior surface slightly above apex of the mandibular incisors, would cause parallel widening of the mandible.

Lim K. Cheung, Qian Zhang [2004]⁴⁰ studied the histologic changes of the new bone and soft tissue formed in the distraction gap of maxillary alveolus after transport distraction on a monkey model and found out that bone formed via intramembranous ossification and teeth in the transport

segment remained viable. This study also did not note any changes in the periodontal ligament and alveolar bone around the teeth involved in the interdental osteotomy and distraction.

Osman Bengi and Gurtun et al (2004)⁵⁹ defined a technique of bone regeneration and osteosynthesis of native preexisting bone. The technique offers a promising treatment alternative for patient with maxillary hypoplasia and a retrognathic mandible. In this case report, an 18.2-year-old girl was treated by pre-maxillary advancement using an individual tooth-borne distraction device. The surgical operation consisted of classical segmental maxillary osteotomy and the distractor was placed in the mouth after the surgical procedure. After seven days latency period the device was activated 0.5mm every 12 hours. A result showed that the anterior crossbite was eliminated in one week and the profile of the patient improved. Treatment was completed using fixed orthodontic appliances.

Seher Sayin and Osman Bengi (2004)⁷¹ evaluated the effects of rapid canine distalization through the distraction of periodontal ligament on the dentoalveolar tissues using semirigid, individual tooth-borne distractors. The study was carried out on 43 canine teeth in 18 patients who required first premolar extractions. The second premolar and first molar were used

as anchor units. Orthodontic models, cephalometric and panoramic radiographs, and standard photographs of all the patients were taken before treatment and after the consolidation period. Periapical radiographs of the canines and anchor units were obtained once a week during the distalization period. The distractor was activated 0.25mm three times a day, and the canines were distalized efficiently on average of three weeks. They concluded that the maxillary canines were distalized an average of 5.76mm with 11.47° distal tipping. The maxillary first molar moved mesially 0.56mm and extruded 0.64mm. The maxillary incisors showed 1.44° of palatal tipping. The mean distal movement of the mandibular canines was 3.5mm with 7.16° distal tipping. Anchorage loss was not observed in the mandibular first molars.

Soon – Jung Hwang, Jong-Geul Jung [2004]⁷⁴ developed a new device with hole implants to distract the alveolar bone vertically in the molar region using a lag screw principle and stated that this technique with the new device is feasible and achieved successful results in this study. Alveolar bone could be distracted not only vertically but also horizontally. The device had four components like distraction screw, hole implant fixture, supporting plate, and temporary short implant.

SUMMARY

This Prospective Clinical Study was conducted in the Department of oral and Maxillofacial surgery, RAGAS DENTAL COLLEGE AND HOSPITAL.

The aim of this study is to apply and evaluate an approach to reduce the overall orthodontic treatment time, by means of dentoalveolar distraction osteogenesis to achieve rapid canine retraction using an indigenously fabricated intra-oral tooth-borne distraction device.

The study objectives included evaluation of the amount of canine retraction, amount of anchorage loss in 1st molars, the degree of tipping of the canine [to evaluate whether bodily movement has occurred], pulp vitality of the canines, bone and gingival changes after distraction osteogenesis and for external root resorption / tooth ankylosis.

Three patients two males and one female in the age range 13-15yrs [mean-14yrs] scheduled for orthodontic treatment with bilateral first bicuspid extractions and subsequent bilateral canine teeth distalization were scheduled for the study and they underwent distraction osteogenesis procedure bilaterally in the maxilla.

The results were evaluated based on clinical, radiographic and study model analysis findings and the patients were evaluated for a period of 3 months post –distraction.

Canines were retracted an amount of 7.5mms in all the cases over 14- 16 days with an anchorage loss of about 0.5mms in the 1st molars in all the cases. Bodily movement of canines with a minimal amount of 7.33 degrees [average] of tipping occurred. Bone and periodontium around the canine teeth were apparently normal and healthy after the removal of the distraction appliance. Canine teeth remained vital after the removal of the distraction appliance [at the end of the whole distraction phase]. No other abnormalities were present both clinically and radiographically during and after the distraction osteogenesis process. Although there were minor problems with the distraction device, it was managed and all the patients tolerated the device well.

CONCLUSION

From our study we conclude that:

1. Canines can be rapidly retracted by Dentoalveolar distraction osteogenesis technique and subsequently the total orthodontic treatment time can be reduced as described in this technique.
2. Bodily movement of canine with a very minimal amount of tipping can be achieved by this technique.
3. This technique can be very useful for patients in whom anchorage requirements are very critical.
4. This technique can be applied safely to move canines maintaining the pulp vitality with establishment of normal and adequate healthy periodontium and bone levels at the end of the treatment.
5. Properly designed Custom-made intra-oral tooth-borne Distraction Device can be very useful for achieving rapid retraction of the canines by means of the distraction osteogenesis technique [transport disc phenomenon] as described in this technique.

Thus, the use of new biomechanical principles and orthodontic appliances to maintain control of the rapid tooth movement awaits further

development before the routine application of this innovative and exciting approach.

BIBLIOGRAPHY

- 1. Abel Garcia Garcia, Manuel Somoza Martin, Pilar Gandara Vila, Jose Manuel Gandara Rey.**

A preliminary morphologic classification of the alveolar ridge after distraction osteogenesis.

Journal of oral and Maxillofacial surgery 62:563-566, 2004.

- 2. Abel Garcia Garcia, Manuel Somoza Martin, Pilar Gandara Vila, Jose Manuel Gandara Rey.**

Palatal approach for maxillary alveolar distraction.

Journal of oral and Maxillofacial surgery.62:795-798, 2004.

- 3. Adi Rachmiel, Ian T.Jackson, Zoran Potparic, Dov Laufer.**

Midface advancement in sheep by gradual distraction. A 1- year follow-up study.

Journal of oral and Maxillofacial surgery 53:525-529,1995.

- 4. Adi Rachmiel, Dov Laufer, Mark levy.**

Lengthening of the mandible by distraction osteogenesis: Report of cases.

- Journal of oral and Maxillofacial surgery 53:838-846,1995.
- 5. Alan s. Herford.**

Use of a plate-guided distraction device for transport distraction osteogenesis of the mandible.

Journal of oral and Maxillofacial surgery 62:412-420,2004.
 - 6. Albino Triaca,Michele Antonini, Roger Minoretti,Beat R.Merz.**

Segmental distraction osteogenesis of the anterior alveolar process.

Journal of oral and Maxillofacial surgery 59:26-34,2001.
 - 7. Almeida M. A, Phillips C, Kula K, Tulloch C**

Stability of the palatal rugae as landmarks for analysis of dental casts.

Angle Orthod 1995 1: 43-48.
 - 8. Al Ruhaimi. K.A.**

Comparison of different distraction rates in the mandible:an experimental investigation.

International journal of oral and Maxillofacial surgery 2001.30:220-227.

9. Altuna G, D. A. Walker and E. Freeman

Surgically assisted rapid orthodontic lengthening of the maxilla in primates — a pilot study

Am J Orthod Dentofacial Orthop 1995; 107:531-536.

10. Ayoub A.F., W. Richardson.

A new device for microincremental automatic distraction osteogenesis.

British journal of oral and Maxillofacial surgery.39, 353-355:2001.

11. Ayoub A.F., W.Richardson. D.Koppel,H.Thompson, M.Lucas, T.Schwarz., L.Smith, J.Boyd.

Segmental mandibular reconstruction by microincremental automatic distraction osteogenesis: an animal study.

British journal of oral and Maxillofacial surgery.39, 356-364:2001.

12. Bailey L'TJ, Esmailnejad A, Almeida M. A

Stability of the palatal rugae as landmarks for analysis of dental casts in extraction and nonextraction cases

Angle Orthod 1996 1:73-78

13. Bell W.H., R.P. Harper, M. Gonzalez, A.M. Cherkashin, M.L. Samchukov.

Distraction osteogenesis to widen the mandible.

British journal of oral and Maxillofacial surgery.1997 [35]. 11-19.

14. Carranza, Murphy.

Orthodontic considerations in periodontal therapy.

Glickmann's clinical periodontology.pp1990. 750-758.

15. Claudio Matteini, and Maurice Y. Mommaerts

Posterior transpalatal distraction with pterygoid disjunction: A short-term model study

Am J Orthod Dentofacial Orthop 2001;120: 498-502.

16. Clinics of North America on distraction osteogenesis. 1999

issue.

17. Cope J.B., M.L. Samchukov.

Mineralization dynamics of the regenerate bone during mandibular osteodistraction.

International journal of oral and Maxillofacial surgery 2001. 30:234-242.

18. Dolanmaz Dogan, Ali Ihya Karaman, Ercan Durmus, Siddik Malkoc

Management of alveolar clefts using dento-osseous transport distraction osteogenesis

Angle Orthod 2003;73:723-729.

19. Douglas A. Roth, Arun .K. Gosain, Joseph. G. McCarthy.

CT scans technique for quantitative volumetric assessment of the mandible after distraction osteogenesis.

Plastic & Reconstructive Surgery. April 1997:1237-1247.

20. Edward B. Seldin, Maria. J. Troulis, Leonard B. Kaban.

Evaluation of a semiburied, fixed-trajectory, curvilinear, distraction device in an animal model.

Journal of oral and Maxillofacial surgery.1999, 57; 1442-1446.

21. Ellen Wenching Ko, Alvaro A. Figueroa, John W. Polley.

Soft tissue profile changes after maxillary advancement with distraction osteogenesis by use of a rigid external distraction device: A 1-year follow-up.

Journal of Oral and Maxillofacial Surgery 2000; 58; 959-969.

22. Eric Jein – Wein Liou, Alvaro Figueroa, John Polley.

Rapid orthodontic tooth movement into newly distracted bone after mandibular distraction osteogenesis in a canine model.

American Journal Orthod Dentofacial Orthop. 2000.117.[391-398].

23. Faruk Ayhan Basciftci, Hasan Hüsnü Korkmaz, Haluk Işeri, and Siddik Malkoc

Biomechanical evaluation of mandibular midline distraction osteogenesis by using the finite element method

- Am J Orthod Dentofacial Orthop 2004;125:706-15.
- 24. Gaggl A. Schultes. G. H. Rainer, H. Karcher.**
Immediate alveolar ridge distraction after tooth extraction - a preliminary report.
British journal of oral and Maxillofacial surgery.2002.40, 110-115.
- 25. Gero S. M. Kinzinger, Siegfried Jänicke, Priv Doz, Dieter Riediger, and Peter R. Diedrich**
Orthodontic fine adjustment after vertical callus distraction of an ankylosed incisor using the floating bone concept
Am J Orthod Dentofacial Orthop 2003;124:582-90.
- 26. Guerrero. C.A., W.H. Bell, G.I. Contasti, A.M. Rodriguez.**
Mandibular widening by intraoral distraction osteogenesis.
British journal of oral and Maxillofacial surgery.1997.[35] 383-392
- 27. Gulati S, Kharbanda O.P, Parkash H**
Dental and skeletal changes after intraoral molar distalization with sectional jig assembly
Am J Orthod Dentofacial Orthop 1998 114: 319-327.
- 28. Häsler R, Schmid G, Ingervall B, Gebauer U**
A clinical comparison of the rate of maxillary canine retraction into

- healed and recent extraction sites - a pilot study
Eur J Orthod 1997; 19: 711-719.
- 29. Hisako, Hikiji, Tsuyoshi Takato, Shigeyuki Mtsumoto.**
Experimental study of Reconstruction of the Temporomandibular joint
using a Bone transport technique.
Journal of Oral and Maxillofacial surgery 2000; 58; 1270-1276.
- 30. Hoggan R Brent , Cyril Sadowsky**

The use of palatal rugae for the assessment of anteroposterior tooth
movements

Am J Orthod Dentofacial Orthop 2001;119:482-8.
- 31. Jacques Buis, Paul Rousseau, Herve Martinez.**
“Distraction” of grafted alveolar Bone in Cleft case using Endosseous
Implant.
Journal of Cranio-Maxillofacial Surgery.
- 32. Jason Cope, Samchukov et al.**
Experimental tooth movement through regenerate alveolar bone. A
pilot study.
American Journal Orthod Dentofacial Orthop.1999; 116.501-505.
- 33. Jason Cope, Samchukov et al.**

Mandibular Distraction Osteogenesis. A historic perspective and future directions.

American Journal Orthod Dentofacial Orthop.1999;115.448-460.

34. Jason B. Cope, Mikhail L. Samchukov

Regenerate Bone Formation and Remodeling During Mandibular Osteodistraction

Angle Orthod 2000;70:99-111.

35. John E-Bilodeau.

Dental Distraction for an adult patient- case report.

American Journal of orthod and Dentofacial Orthop 2003; 123; 683-9.

36. Kai-Olaf Henkel, Lian ma, Luduing Jonas, Jan-Hendrik Lenz.

Closure of vertical alveolar Bone defects with guided Horizontal distraction osteogenesis; an experimental study in pigs and first clinical results.

Journal of Cranio-Maxillofacial Surgery 2001; 29; 249-253.

37. Keles A, Sayinsu K

A new approach in maxillary molar distalization: Intraoral bodily molar distalizer

Am J Orthod Dentofacial Orthop 2000 117:39- 48

38. Kole et al.

Historical Development and Evolution of Craniofacial Distraction Osteogenesis.

In: Samchukov M L, Cope J B, Cherkashin A M, eds.

Craniofacial Distraction Osteogenesis. St.Louis, MO: Mosby: 2001: 3-17.

39. Kourosh Tavakoli, W.R. Walsh, Fiona Bonar.

The role of latency in mandibular osteodistraction.

Journal of Cranio-Maxillofacial Surgery 1998; 26; 209-219.

40. Lim K. Cheung, Qian Zhang.

Healing of maxillary alveolus in transport distraction osteogenesis for partial maxillectomy.

Journal of Oral and Maxillofacial Surgery 2004; 62; 66-72

41. Lindsey R. Douglas, J. Burton Douglass, Philip J. Smith.

Intra-oral mandibular distraction osteogenesis in a patient with severe micrognathia secondary to TMJ ankylosis using a tooth and Bone-Anchored device (PIT) device: A case report.

Journal of Oral and Maxillofacial Surgery 2000; 58; 1429-1433.

42. Lindsey R. Douglas, J. Burton Douglass, Philip J. Smith.

Intra-oral distraction osteogenesis in the baboon mandible using a tooth and Bone-Anchored appliance.

Journal of Oral and Maxillofacial Surgery 2000;58; 49-54

43. Liou JW Eric, Shing Huang.

Rapid canine retraction through distraction of the periodontal ligament.

American Journal of orthod and Dentofacial Orthop 1998; 114[372].

44. Maria J. Troulis, Julie Glowacki, David H. Perrott, Leonard B. Kaban.

Effect of latency and rate on Bone formation in a porcine mandibular distraction model.

Journal of Oral and Maxillofacial Surgery 2000; 58; 507-513.

45. Maria J. Troulis, Julie Glowacki, David H. Perrott, Leonard B. Kaban.

Endoscopic mandibular osteotomy and placement and activation of a semiburied destructor.

Journal of Oral and Maxillofacial Surgery 1999; 57; 1110-1113.

46. Maria.J.Troulis, Carolyn Coppe, Mary Jane O' Neill, Leonard.B.Kaban.

Ultrasound: Assessment of the distraction osteogenesis wound in patients undergoing mandibular lengthening.

- Journal of Oral and Maxillofacial Surgery.2003;61.1144-1149.
- 47. Marinho Del Santo, Cesar A. Guerrero, Peter H. Buschang, Jeryl D. English, Mikhail L. Samchukov, and William H. Bell**
- Long-term skeletal and dental effects of mandibular symphyseal distraction osteogenesis.
- Am J Orthod Dentofacial Orthop 2000;118:485-93.
- 48. Martin chin, Bryant A-Toth.**
- Distraction osteogenesis in maxillofacial surgery using internal devices. Review of 5 cases.
- Journal of Oral and Maxillofacial Surgery 1996; 54; 45-53.
- 49. McCarthy Joseph.**
- Textbook on Distraction Osteogenesis of the Craniofacial Skeleton.
- 50. Michael S. Block, G. Dodd Brister.**
- Use of distraction osteogenesis for maxillary advancement. preliminary results.
- Journal of Oral and Maxillofacial Surgery 1994; 52; 282-286.
- 51. Michael S. Block, Andrew Chang, Deneen Cervini, G. Bradley Gottsegen.**
- Anterior maxillary advancement using Tooth-supported distraction osteogenesis.

- Journal of Oral and Maxillofacial Surgery 1995; 53; 561-565.
- 52. Michael S. Block, Andrew Chang, Craig Crawford.**
- Mandibular alveolar ridge augmentation in the Dog using distraction osteogenesis.
- Journal of Oral and Maxillofacial Surgery 1996; 54; 309-314.
- 53. Michael S. Block, John Daire, John Stover, Murray Matthews.**
- Changes in the inferior alveolar nerve following mandibular lengthening in the dog using distraction osteogenesis.
- Journal of Oral and Maxillofacial Surgery. 1993; 51: 652-660.
- 54. Mommaerts. M.Y.**
- Transpalatal distraction as a method of maxillary expansion.
- British Journal of Oral and Maxillofacial Surgery 1999; 37; 268-272.
- 55. Mommaerts. M.Y.**
- Bone anchored intraoral device for trans mandibular distraction.
- British Journal of Oral and Maxillofacial Surgery. 2001.[39] 8-12.
- 56. Niederhagen B., Braumann B, S. Berge, T. Appel, J. J. Von Lindern.**
- Tooth- Borne distraction of the mandible. An experimental study.

- International Journal of Oral and Maxillofacial Surgery 1999; 28; 475-479.
- 57. Niederhagen B., Braumann B, S. Berge, T. Appel, J. J. Von Lindern.**
- Tooth – Borne distraction to widen the mandible. Technical note.
- International Journal of Oral and Maxillofacial Surgery 2000; 29; 27-28.
- 58. Norimichi Nakamoto, Hiroshi Nagasaka et al.**
- Experimental tooth movement through mature and immature bone regenerates after distraction osteogenesis in dogs.
- American Journal Orthod Dentofacial Orthop.2002.121;385-395.
- 59. Osman Bengi A., A. Ümit Gürton, Kemal Murat Okcu, Yavuz Sinan Aydintug**
- Premaxillary distraction osteogenesis with an individual tooth-borne appliance
- Angle Orthod 2004;74:420-431.
- 60. Padwa B. L., Kearns G. J. Todd R, M. Troulis, J. B. Mulliken, L.B. Kaban.**
- Simultaneous maxillary and mandibular distraction osteogenesis with a semiburied device.

- International Journal of Oral and Maxillofacial Surgery 1999; 28; 2-8.
- 61. Pascal X. Pinto, Maurice V. Mommaerts, Walter Jacobs.**
Immediate post expansion changes following the use of the Transpalatal distractor.
Journal of Oral and Maxillofacial Surgery 2001; 59; 994-1000.
- 62. Peter Kebler, Jorg Wiltfang, Friedrich Wilhelm Neukam.**
A New distraction device to compare continuous and discontinuous bone distraction in mini-pigs; a preliminary report.
Journal of Cranio-Maxillofacial Surgery 2000; 28; 5-11.
- 63. Peter Kebler, Jorg Wiltfang, Friedrich Wilhelm Neukam.**
Distraction osteogenesis of the maxilla and midface using a subcutaneous device: report of 4 cases.
British Journal of Oral and Maxillofacial Surgery 2001; 39; 13-21.
- 64. Pilar Rubio – Bueno, Esther villa, alberto Carreno, Luis Naval.**
Intra-oral mandibular distraction osteogenesis, Special attention to treatment planning.
Journal of Cranio-Maxillofacial Surgery 2001; 29; 254-262.
- 65. Pilon JJGM, Maltha JC**

Magnitude of orthodontic forces and rate of bodily tooth movement.

An experimental study.

American journal of orthod and dentofacial orthopaedics.110.[16]

1996.

66. Ploder.O, W.Mayr, G.Schnet, E.Unger, R.Ewers,

Mandibular lengthening with an implanted motor-driven device:
preliminary study in sheep.

British Journal of Oral and Maxillofacial Surgery.1999 [37],
273-276.

67. Profitt WR, Fields HW.

Fixed and removable appliances.

Contemporary orthodontics 1993 pp 317-373.

68. Reha S. Kisnisci, Haluk Iseri, Hakan H. Tuz, Ayse T. Altug.

Dentoalveolar distraction osteogenesis for rapid orthodontic canine
retraction.

Journal of Oral and Maxillofacial Surgery 2002; 60; 389-394.

69. Reha S. Kisnisci, Stephen D. Fowel, and Bruce N. Epker

Distraction osteogenesis in Silver Russell syndrome to expand the
mandible

Am J Orthod Dentofacial Orthop1999;116:25-30.

70. Reitan K

Biomechanical principles and reactions.

Graber Tm Swain. Orthodontics- current principles and techniques. pp
101-192 mosby.

71. Seher Sayn, Osman Bengi, Umit Gurton, Kerim Ortakolu.

Rapid canine distalization using distraction of the periodontal
ligament. A preliminary clinical validation of the original technique.

The Angle Orthodontist. 2004. vol 74. no.3 .304-315.

72. Selcuk Basa, Evren uner, Mete Citir, Kerem Aras.

Reconstruction of a large mandibular defect by distraction
osteogenesis: A case report.

Journal of Oral and Maxillofacial Surgery 2000; 58; 1425-1428.

73. Shaw W.C., N.A. Mandall, C.R. Mattick.

Ethical and scientific decision making in distraction osteogenesis.

Cleft-Palate-Craniofacial Journal NOV 2002; 39; 6.

**74. Soon-Jung Huang, Jong – Geul Jung, Ji-ung Jung, Seung-Hyun
Kyung.**

Vertical alveolar Bone distraction at molar region using lag screw
principle.

Journal of Oral and Maxillofacial Surgery 2004; 62; 787-794.

75. Stanley Braun, J. Alexandre Bottrel, and Harry L. Legan

Condylar displacement related to mandibular symphyseal distraction
Am J Orthod Dentofacial Orthop 2002;121:162-5.

- 76. Stephen L.K. Yen, John Gross, Peter Wang, Dennis-Duke Yamashita.**

Closure of a large alveolar cleft by Bone transport of a posterior segment using orthodontic arch wires attached to Bone: Report of a case.

Journal of Oral and Maxillofacial Surgery 2001; 59; 688-691.

- 77. Stephen Warren, Pierre Bouletreau et al.**

Molecular Biology in Distraction Osteogenesis.

Internal Journal of Oral and Maxillofacial Surgery 2001;23. 231-236.

- 78. Steven R. Cohen, William Boydston, Fernando D. Burstein, Roger Hudgins.**

Monobloc distraction osteogenesis during infancy: report of a case and presentation of a new device.

Plastic and Reconstructive Surgery. June 1998.

- 79. Steven Smith, Rohit Sachdeva, Jason Cope.**

Evaluation of the consolidation period during osteodistraction using computed tomography.

American Journal Orthod Dentofacial Orthop.1999;116.254-263.

- 80. Suzanne, V. Stucki, Mc Cormick, Ronald D. Mizrahi Robert M. Rox, Thomas Romo.**

Distraction osteogenesis of the mandible using a submerged Intra-oral device: A report of 3 cases.

Journal of Oral and Maxillofacial Surgery 1999; 57; 192-198.

- 81. Tae Ki Chul, Seiw Ging Gong, Song Ki Min, Song Whan Oh**

Use of distraction osteogenesis in cleft palate patients

Angle Orthod 2003;73:602-607.

- 82. Toshiyuki Hagiwara, William H. Bell.**

Effect of electrical stimulation on mandibular distraction osteogenesis.

Journal of Cranio-Maxillofacial Surgery 2000; 28; 12-19.

- 83. U. Meyer, T. Meyer, W. Schlegel, H. Scholz, U. Joos.**

Tissue differentiation and cytokine synthesis during strain-related bone formation in distraction osteogenesis.

British Journal of Oral and Maxillofacial Surgery 2001[39]22-27.

- 84. U. Meyer, T. Meyer, Hans-Peter Wiesmann U. Joos.**

The effect of magnitude and frequency of interfragmentary strain on the tissue response to distraction osteogenesis.

Journal of Oral and Maxillofacial Surgery 57.1331-1339,1999.

- 85. U. Meyer, T. Meyer U. Joos.**

Decreased expression of osteocalcin & osteonectin in relation to high strain and decreased mineralization in mandibular distraction osteogenesis.

Journal of Cranio-Maxillofacial Surgery 1999 [27] 222-227

86. U. Meyer Hans-Peter Wiesmann U. Joos.

Strain-related bone remodeling in distraction osteogenesis of the mandible.

Plastic and Reconstructive surgery March 1999.vol 103.

87. William H. Bell, Marianela Gonzalez, Mikhail L. Samchukov, Cesar A. Guerrero.

Intra-oral widening and lengthening of the mandible in baboons by distraction osteogenesis.

Journal of Oral and Maxillofacial Surgery 57:548-562 [1999]

88. Wiltfang J.,P.Kebler, Merten, Neukam.

Continuous and intermittent bone distraction using a microhydraulic cylinder: an experimental study in mini-pigs.

British Journal of Oral and Maxillofacial Surgery.2001. [39]2-7.

89. Yoshihiro Sawaki, HajimeOhkubo, Hideharu Hibi, Minoru Ueda.

Mandibular lengthening by distraction osteogenesis using osseointegrated implants and an intra-oral device: a preliminary report.

Journal of Oral and Maxillofacial Surgery .54;594-600 [1996].