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A RETROSPECTIVE ANALYSIS EVALUATING THE VALIDITY OF THE ELIAN CLASSIFICATION FOR TREATMENT OF EXTRACTION SOCKETS

By

Paul Seibel, DMD

Submitted to the Faculty of the
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ABSTRACT

A Retrospective Analysis Evaluating the Validity of the Elian Classification for Treatment of Extraction Sockets:

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Thesis directed by: Brandon Coleman, Assistant Director, Periodontics

This retrospective study of a double-blinded randomized clinical trial, evaluated the validity of the Elian classification system for predicting post-surgical outcome and determine if site-specific factors influence the outcome. This study sought to find relationships between anatomic location (anterior, posterior), jaw site (maxillary, mandibular), Elian classification type (type I, II bone) to the amount of retained alveolar bone after four months healing period.

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INTRODUCTION

STATEMENT OF THE PROBLEM

Implant therapy has been shown to be a predictable treatment option and has achieved a 10-year survival rate of more than 90%, and the use of dental implants has been an increasingly popular treatment option to replace missing teeth. (Misch, 1990)

The bone quality or density at the time of implant placement is a critical factor utilized by clinicians to assess the degree of primary stability and clinical success. In a study evaluating various length and diameter Branemark implants in all bone types, bone quality was found to be the main determinant in predicting failure. (Jaffin and Berman., 1991) Numerous classification systems for measuring bone quality and quantity, such as Linkow 1970, Lekholm & Zarb 1985, and Misch 1988 have been presented in the literature as important predictors for implant success. However, despite the variety of systems that have been proposed, there is no universally accepted classification system for bone or sockets. Although some systems have gained more popularity than others, no bone or socket classification systems have been validated for any clinical applications to date. Clinicians are interested in new classification systems that are organized and predictive so treatment outcomes can be communicated to the patient. However, few systems have been scrutinized for reliability, reproducibility, and clinical validity. Based on a thorough Pubmed and Google Scholar search, none have been validated.

Many of the classification systems utilized today differ in their measurements of bone quality and quantity, leading to confusion and difficulty in comparing results between studies. Poor objectivity and reproducibility are deficiencies of the Lekholm & Zarb classification system as tactile perception is highly subjective. Another limitation of the Lekholm & Zarb classification is that variations in the cortical-to-trabecular bone ratio occur in each bone type and thus cannot give precise details of bone quality. (Linck et al., 2015) In a study comparing the perception of bone quality at implant sites utilizing the Misch classification with histomorphometric assessment of bone cores, clinicians' were only able to distinguish between type D1 bone (dense) and D4 bone (soft) but failed to distinguish type D2 and D3 bone. (Trisi and Rao, 1999) In another study, tactile perception was shown to have a minor influence on preoperative bone assessment. (Linck et al, 2015) A classification system that is objective, that can be applied preoperatively to access the quality and quantity of bone, and clinically valid has not been reported in the literature.

In 2007, Elian presented a new extraction socket classification system based on the presence or absence of buccal hard and soft tissue immediately after tooth extraction (see Figure 1). Type I extraction sockets indicate normal buccal hard and soft tissue, and are the most predictable to treat. Type II extraction sockets indicate partial loss of buccal hard tissue but normal buccal soft tissue, and can be the most difficult to diagnose. Type III extraction sockets have significant buccal hard and soft tissue loss, and therefore are the most difficult to treat and require additional hard and soft tissue augmentation. (Elian et. al, 2007) Currently, the Elian classification system is being used more as a communication tool to provide the clinician guidance for dental implant placement.

In summary, reliable quantification of bone loss and the relationship of the loss to clinical outcomes are important for treatment planning. Alveolar bone characteristics such as quality, quantity, and density are important variables used to assess treatment outcomes. The Elian classification is a system that purports to quantify bone loss and potential application as a prognostic tool for future implant placement. However, it has not been validated and the evidence regarding its accuracy and clinical methods used to assess alveolar bone characteristics is insufficient. When utilizing this system, knowledge of the most favorable combination of classification type and socket location would lead to more predictable and better treatment outcomes. However at present, there is no research validating the Elian classification with respect to a relationship to the treatment outcome.

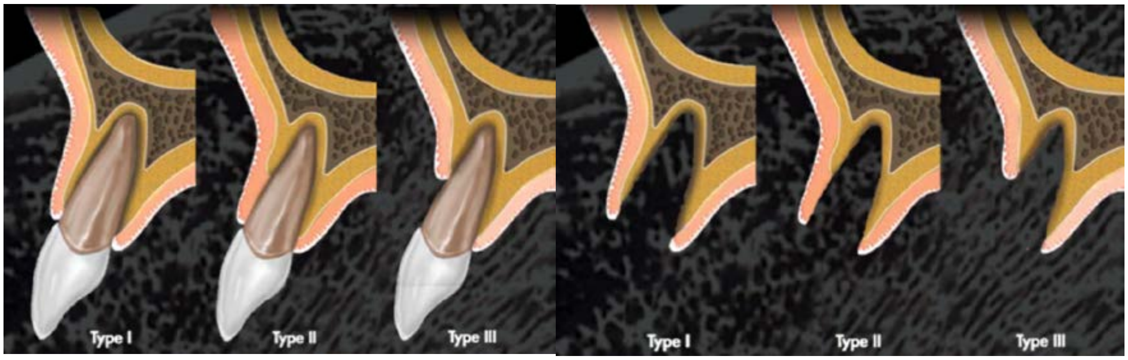


Figure 1: Elian Classification

SIGNIFICANCE

There is little evidence validating the Elian classification with regards to post-surgical outcome. If the Elian classification system could be validated, then the clinician may be able to use information obtained in this study in the treatment planning process to determine predictably which classification type has the best prognosis. For the Army, maximizing the amount of bone regenerated could potentially decrease the amount of additional surgeries, decrease the military personnel's time away from their duties, and increase readiness.

REVIEW OF THE LITERATURE

TOOTH EXTRACTION AND BONE LOSS

Dental extraction is a very common procedure to treat irreparable damage to the tooth structure or supporting tissues, with periodontal disease and caries being the most frequent reasons for tooth extraction in adults and children. (Alsheneifi et al., 2001) According to data from the National Health and Nutrition Examination Survey conducted from 2011-2012, tooth loss and edentulism were present in nearly 19 % of adults 65 years and older. (Dye et al., 2015) Implant placement is becoming a common and popular treatment for extraction sites because of implant longevity, esthetics and ease of maintenance. However, adequate bone at the site is required for long-term stability and a predictable outcome for the implant.

Although the extraction socket usually heals uneventfully, marked changes in the dimensions of the ridge arise frequently, resulting in a deficiency of the alveolar ridge bone. Following extraction of a tooth, major changes in the alveolar bone occur in the form of atrophy, with the greatest bone loss occurring on the buccal aspect leading to horizontal loss of the alveolar ridge. (Van der Weijden, 2009) If the severity of this atrophy becomes too extensive, it becomes problematic for the placement of a dental implant. Ridge preservation becomes a valid solution to counteract this atrophy by reducing the overall resorption rate and allowing for a more esthetic and functional prosthesis.

The requirement for assessing alveolar ridge bone in dental implant treatment is twofold: (1) as a diagnostic tool to assess whether the alveolar ridge bone is sufficient for implant placement; (2) as a prognostic tool to predict the probability of success or failure. (Ribeiro-Rotta et al. 2010) The quality and quantity of the buccal plate and soft tissue are key determinants for the post-surgical healing and treatment selection.

Bone Quality and Quantity

Numerous classification systems for measuring bone quality and quantity have been presented in the literature, such as those by Linkow 1970, Lekholm & Zarb 1985, Misch 1988, and Cavallaro & Greenstein 2009. Classification systems can further be distinguished based on sockets (immediately after an extraction) and bone (after the alveolar ridge has healed completely). The quality and quantity of available bone is an important feature to implant dentistry. The quality of bone reflects the biomechanical properties such as strength and modulus of elasticity. The quality, or density, of bone has an effect in treatment planning, implant design, surgical approach, and healing time. (Misch 1990) Bone quantity is the amount of available bone in the edentulous area and is measured by height, width, length, angulation, and crown height space.

Lekholm & Zarb classified bone quality into four types and quantity into five types, type 1-4 bone and type A-E bone respectively; the type is based on radiographic assessment, the resistance experienced by the clinician, and the amount of available cortical and cancellous bone at the time of implant site preparation (see Figure 3). The Misch classification was proposed in 1988 to describe four bone density groups independent of the regions of the jaw and classified bone density into four groups, D1 through D4, based on the clinical hardness or quality of bone experienced by the clinician. Type D1 bone (dense cortical bone) is like drilling oak or maple wood, D2 (dense to porous cortical bone and dense cancellous bone) is similar to white pine or spruce wood; D3 (porous cortical bone and fine cancellous bone) is similar to balsa wood; and D4 (little cortical bone and fine cancellous bone) is similar to Styrofoam. (Misch 1993) Despite the number of classification systems presented in the literature, they all have deficiencies and failure for validation.

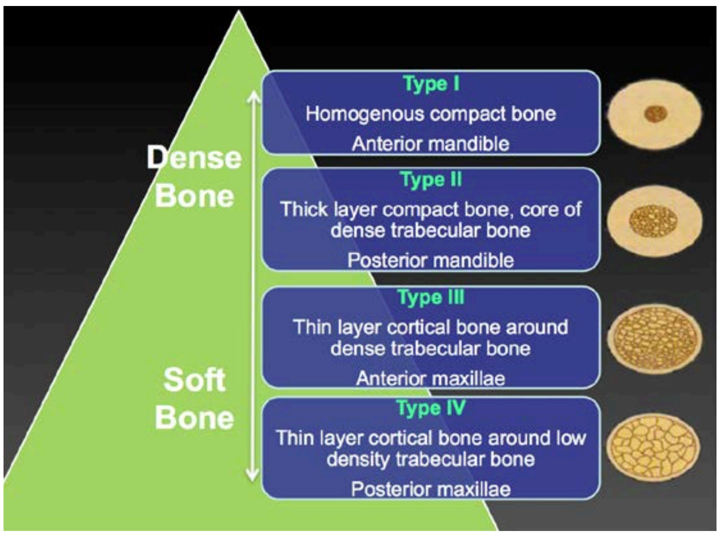


Figure 3: Lekholm and Zarb Classification

BONE BIOLOGY: STRUCTURE, METABOLISM, AND PHYSIOLOGY

Osteoblasts, Osteoclasts, and Osteocytes

Following extraction of a tooth, the alveolar ridge undergoes an inevitable bone remodeling process that influences implant therapy of the edentulous area, with changes occurring at the molecular, cellular, and tissue levels. Extraction of a tooth stimulates a cascade of cellular events involving three principal types of bone cells: osteoblasts, osteocytes, and osteoclasts. Osteoblasts are the primary cells responsible for bone formation and are located on bone surfaces exhibiting active matrix deposition. Osteocytes are osteoblasts that have become trapped within the mineralized bone matrix in lacunae. They remain in contact with other cells *via* thin cellular processes that traverse through canaliculae, and help regulate blood-calcium levels, sense mechanical loading, and signal this information to other cells within bone (Tomkinson, 1997). Osteoclasts develop by fusion of monocytes, and are multi-nucleated and mobile. They are responsible for bone resorption, and contain a high amount of vacuoles comprised of lysosomes. At a site of bone resorption, the activated osteoclast opposes the surface of the bone to allow cell secretion of protons and proteases, causing bone resorption.

The Alveolar Process

The alveolar process develops in conjunction with tooth eruption and is a tooth-dependent tissue that surrounds a fully developed tooth. In the maxilla, the alveolar process consists of a ridge on the inferior surface and on the mandible it is a ridge on the superior surface. The alveolar bone consists of the alveolar bone proper and supporting bone. The alveolar bone proper (otherwise known by the histological term bundle bone) forms the lining of the tooth socket, surrounding the tooth, and is made of compact bone. Sharpey's fibers connect the bundle bone and tooth via the periodontal ligament. Bundle bone is a highly tooth dependent structure. In an experimental study on dogs, it was observed that the buccal portion of crestal bone (the most coronal portion of the alveolar crest) consisted mostly of bundle bone and the lingual aspect contained a combination of bundle and a mature type of bone called lamellar bone. (Araujo and Lindhe 2005) Histological and dimensional changes occur following tooth extraction, with resorption of bundle bone and replacement by immature woven bone and osteoclastic activity on the buccal walls adjacent to the extraction socket. Bone modeling and remodeling takes place that result in a net reduction of the alveolar ridge. (Araujo et.al, 2015)

SOCKET HEALING

Histological Changes

Wound healing is a process that occurs where the skin or other body tissue repairs itself after injury. An extraction socket is a specialized example of healing by secondary intention, which occurs when the wound edges are far apart and cannot be brought together. The majority of research in extraction socket healing has been in animals.

However, it is well understood that animals heal about three to five times faster than humans.

After extraction of a tooth, a blood clot fills the extraction socket within the first 24 hours. The blood clot is then replaced by granulation tissue by day 7. By day 21, the granulation tissue is replaced by collagen and bone begins to form at the base and periphery of the socket. Two-thirds of the extraction socket fills with bone by the sixth week. Soft tissue coverage of the extraction socket begins as early as 24 hours but takes as long as 35 days to cover the socket completely. Bone fill of the socket progresses from the apex and periphery, and finally progresses towards the center of the extraction socket. Complete bone fill can take up to four months. (Amler, 1969) (Hammerle et al., 2004)

In an experimental study in dogs, biopsy specimens were taken at 1, 2, 4, and 8 weeks of healing. (Araujo and Linde, 2005) By the first week after tooth extraction, a blood clot fills the extraction socket, and osteoclasts begin to line and resorb the bundle bone of the buccal and lingual bone walls. By week 2, immature woven bone begins to form at the apical and lateral parts of the socket and a provisional connective tissue matrix forms more centrally. At 4 weeks, immature woven bone occupies the entire socket and begins to be replaced by mature lamellar bone. By 8 weeks, cortical bone forms at the entrance to the socket. The immature woven bone formed at four weeks is replaced by bone marrow and mature lamellar bone. Ongoing hard tissue resorption occurs on the buccal coronal plate, presumably due to more bundle bone composition, causing it to shift apical to its lingual counterpart.

It is also well established in the literature that separation of the periosteum during flap elevation results in vertical height bone resorption of the thin buccal plate. In an experimental study in dogs following temporary and permanent flap elevation, permanent flap elevation resulted in resorption of bone 2-10 days after elevation with incomplete repair when compared to temporary flap elevation. (Wilderman et al, 1960, 1964)

Thick versus Thin Gingival Biotype

Tissue biotype or thickness have been associated with the successful outcomes of both periodontal and implant therapy. In a study measuring gingival thickness found that two-thirds of patients had thick biotype, a broad zone of keratinized tissue, and flat gingival margins. The remaining one-third had thin biotype, a narrow zone of keratinized tissue, and highly scalloped gingival margins. (De Rouck et al., 2009) Thick biotype is classified as have a gingival thickness of greater than 2mm. In comparison with thinner biotypes, thick gingival biotypes with an intact buccal plate have a reduced risk for buccal plate resorption. When the buccal plate undergoes resorption, the need for additional augmentation rises, and an immediate implant is not recommended. (Hammerle et al., 2004) In a study of immediate implants placed in non-ideal positions (facially), 85 percent of thin biotypes had greater than 1mm of recession versus 66.7 percent in thick biotypes. (Lee et al., 2011) In a study evaluating the peri-implant mucosa of maxillary anterior single implants, it was found that thick biotype has a lower risk for interproximal papilla collapse when compared to thin biotype. It was also suggested that the interproximal papilla has a better chance at being maintained to the normal osseous level (4.5 mm from the underlying bone) with thick peri-implant biotype. (Kan et al., 2003) Another study comparing thin tissue, thin tissue thickened by acellular dermal matrix allograft, and thick tissue around 97 Straumann implants found significantly less bone loss around implants placed in naturally thick mucosal tissues and suggests augmenting thin soft tissue may reduce crestal bone loss. (Puisys et al., 2015) In a systematic review, implants placed in sites with initially thick peri-implant mucosa have less radiographic bone loss in the short term. (Suarez-Lopez del Amo 2016)

Alveolar Ridge Remodeling

Resorption of bone around an extraction socket takes place in two overlapping phases. (Araujo and Lindhe, 2005) Phase 1 consists of resorption of the bundle bone that had once had surrounded the tooth, followed by replacement with an immature type of bone called woven bone. Since the buccal portion of crestal bone is comprised of mostly bundle bone, substantial vertical loss occurs at the buccal crest. Phase 2 consists of osteoclastic activity on the buccal wall adjacent to the extraction socket. During phase 2, most of the resorption occurs on the buccal or facial wall and minor resorption on the palatal or lingual wall, presumably because a palatal/lingual flap is not elevated. The reason for this extensive resorption is unclear. It has been suggested that severance of the blood supply to the bone may be the cause, with reduced blood flow leading to osteocyte death, and consequently atrophy of the surrounding mineralized bone. (Araujo and Lindhe, 2005) The resorption of the buccal crest bone, which consists mostly of bundle bone, causes a relocation of the ridge in a palatal/lingual position. (Barone 2014) This biological process of extraction socket healing with resorption and net bone loss has a significant influence on the treatment plan (e.g., immediate versus delayed implant placement, or alternative prosthetic treatments).

Dimensional Changes

As an extraction socket heals, histological and anatomical changes occur with both vertical and horizontal ridge resorption. Studies have shown that major hard and soft tissue changes occur in the first 12 months following extraction of a tooth. In a 12-month prospective study, bone formation in the alveolus and changes of the alveolar process following tooth extraction were assessed using study casts, linear radiographic analyses, and subtraction radiography. (Schropp et al., 2003) The width of the alveolar ridge was reduced by 50% (5-7mm) during the observation period (mean 12.0 mm to 5.9 mm) immediately after tooth extraction, with about two-thirds of this reduction occurring in the first three months. The majority of the loss of ridge height occurred in the first 3 months. In another study, bone loss six months after extraction accounted for 40% loss of bone height and 60% loss of width. (Lekovic et al 1998) Significant dimensional changes begin in the eight weeks following a tooth extraction associated with increased osteoclastic activity and resulting in pronounced loss of bone in the buccal dimension. (Araujo and Lindhe, 2005) This buccal dimensional loss can be as great as 4 mm. (Van der Weijden, 2009)

Measurement of Dimensional Changes

Traditionally, conventional radiographic images such as panoramic and periapical images have been used to assess the height of the alveolar ridge and status of adjacent structures in the mesiodistal dimension. With the advent of Cone-Beam Computed Tomography (CBCT), measurement of the quality and quantity of bone can be achieved with ease and relatively low radiation risk to the patient. Dosage for each small volume scan with the 3D Accuitomo 170 CBCT machine is 30 μSv, roughly the dose of 1.5 digital panoramic radiographs. (Theodorakou 2012)

Subtractive radiography allows for greater visualization of radiographic changes between a pair of radiographs by subtracting the unchanging background or baseline radiograph. Subtractive radiography using CBCT has recently been published in the dental literature and allows for more accurate quantitative measurements. (Reddy and Jeffcoat 1993, Howerton & Mora 2008)

Clinical Relevance of Ridge Preservation

As bone slowly grows into a healing extraction socket, there is a simultaneous and predictable resorption process occurring resulting in a shorter, narrower alveolar ridge. Resorption often exceeds three to four mm horizontally and vertically in the first six months. This loss of alveolar bone may produce esthetic and functional deficiencies in the patient's mouth, especially in the anterior region. (Wang et al, 2004) Loss of alveolar ridge width and height can complicate placement of an endosseous dental implant since there must be adequate bone to completely surround the dental implant. In a study comparing implant placement in ridge preserved versus non-ridge preserved sockets, it was concluded that ridge preservation allows placement of larger diameter implants and less additional bone grafts at the time of placement. (Barone et.al, 2012) In a study comparing dimensional changes, the need for maxillary sinus floor elevation, and wound healing of ridge preserved and non-ridge preserved extraction sockets, it was found that the main advantage of ridge preservation in the posterior maxilla is a reduction for the need for maxillary sinus augmentation. (Rasperini et al, 2010) In a study comparing ridge preservation with FDBA and extraction alone, grafting extraction sockets reduces the dimensional loss in width to 1.2 ± 0.9mm versus the extraction alone group which losses 2.6mm±2.3mm. (Iasella et al, 2003) Consequently, various strategies have been developed with the aim of preserving bone. Failure to preserve the alveolar ridge at the time of extraction may require additional augmentation (Guided Bone Regeneration) using autologous bone graft harvested from a second site such as the hip or external oblique ridge of mandible. The additional surgical site leads to increased postoperative pain, morbidity, and time away from work.

MATERIALS TO PRESERVE BONE

Barrier Membrane Use

Membranes have been used to act as barriers to isolate the extraction socket from infection and epithelial invasion during the healing process. In a study comparing alveolar ridge preservation with and without a barrier membrane, a significant reduction in bone loss was observed when extraction sockets were treated only with a membrane or a combination with bone graft. At 6 months, the average loss of alveolar ridge height and width of the extraction socket treated only with a barrier membrane was -0.38 mm and -1.32 mm respectively. The average loss of alveolar ridge height and width of extraction sockets that were allowed to heal without a membrane was a significantly greater -1.5mm and -4.56 mm respectively. The bone loss in extraction sockets treated with only a membrane was also considerably less than extraction sockets treated without a membrane. Also, at 6 months more internal bone fill was associated with the extraction sockets utilizing only a barrier membrane. (Lekovic et.al, 1998)

A wide range of barrier membranes are used today, ranging from expanded poly-tetrafluoroethylene (ePTFE), high-density polytetrafluoroethylene (dPTFE), collagen, amnion chorion membrane, acellular dermal matrix, and titanium mesh. However, these can be grouped into two major categories: resorbable and non-resorbable.

Allografts

Various bone-grafting materials are available today for use in efforts to counter the bone resorption that is a common consequence of tooth loss. Freeze-dried bone allograft (FDBA) and demineralized particulate freeze-dried bone allograft (DFDBA) are the two primary forms of allografts available for ridge preservation procedures. FDBA is an osteoconductive non-vital implant material that acts as a scaffold for ingrowth of precursor osteoblasts from adjacent tissue into a bony defect. DFDBA can promote osteoconduction and osteoinduction. Osteoinduction occurs when undifferentiated cells are induced to become activated osteoblasts. (Wang, 2005) In a study comparing DFDBA and FDBA, DFDBA was shown to have a greater percentage of newly formed vital bone and less residual grafting material in comparison to FDBA when placed into extraction sockets. Both DFDBA and FDBA have been shown to be equally effective at ridge preservation. (Wood et al, 2012)

Xenografts

The use of bovine, equine, or porcine bone has been extensively reported in the literature. Xenografts have the advantages of being osseoconductive and slowly resorbing with as much as 31 percent remaining after nine months. (Artzi et al., 2000) Particularly, cancellous porous bovine bone mineral (PBBM) has been shown to have an average bone fill of 82 percent with newly formed bone adhered to it. (Artzi et al., 2000)

SUCCESS OF RIDGE PRESERVATION AFTER TOOTH LOSS

Alveolar ridge preservation is now a common procedure used to ameliorate the bone resorption process that follows tooth extraction. When comparing non-preserved sites to preserved sites, non-preserved sites show a continuous dimensional loss over 12 weeks. (Flugge et.al, 2015) In a systematic review and meta-analysis of non-molar sites, ridge preservation was found to be an effective treatment option to prevent bone loss after tooth extraction. In the same study, a subgroup analysis showed that the use of a membrane, flap elevation, and the use of a xenograft or allograft may enhance midbuccal and midlingual preservation of bone height. (Avila-Ortiz et.al, 2014) In another study, approximately 85% of the original ridge dimension was maintained four months after ridge preservation with a xenograft and collagen membrane. (Cardaropoli et.al, 2008)

IMPLANT SUCCESS IN REGENERATED SITES

Implants placed in regenerated bone have been reported in the literature to have similar success and survival rates as implants placed in native bone. In a systematic review in 2003, it was found that the survival rates of implants placed in regenerated sites having similar survival rates (97%) as implants placed in native bone. (Fiorellini and Nevins,

2003) In a follow-up study to this systematic review, regardless of the bone filler used- autogenous, DFDBA, organic bovine, tricalcium phosphate, or collagen sponge or ePTFE membrane alone- can achieve a high percentage bone-to-implant contact (BIC). (Fiorellini et al, 2007) Another study found a survival rate of 92.3% for regenerated sites and 98.3% in native bone sites over a 76-month period. (Corrente et al, 2000)

SITE SPECIFIC FACTORS

Anterior versus Posterior Sites

There are limited published studies comparing anatomical (site-specific) locations (Maxilla vs Mandible, Anterior vs Posterior) regarding an influence on ridge preservation outcomes. A study comparing ridge preservation and extraction alone in the maxillary anterior and mandibular premolar region showed that the loss of ridge width could reach as high as 4 to 5 mm. The reported mean width of the extraction group was 6.4 mm and ridges below this value can be problematic for placement of a 4 mm diameter implant, especially in an area where esthetics are important. Due to the amount of ridge loss that occurred in both groups, it was suggested that both an extra- (Buccal overlay graft) and intra-socket grafting may be preferable in the anterior maxilla. (Iasella et al., 2003) In a study comparing an extraction socket graft and buccal overlay graft showed that a buccal overlay graft significantly prevented ridge resorption in the horizontal dimension and maintained the buccal contour, mean ridge loss of 1.6 ± 0.8mm versus 0.3 ± 0.9mm, respectively. (Poulias et al., 2013) A ridge preservation study using a non-resorbable dPTFE membrane alone showed that horizontal bone loss was greater in the anterior region than the posterior in both jaws. (Hoffmann et al., 2008)

RESORPTION OF THE ANTERIOR MAXILLA

Bone quality and quantity vary with jaw site and have been reported to have an effect on implant success. Pietrolovski & Massler 1967 reported that a loss in the horizontal dimension in the maxillary anterior region could reach as great as 3.5 mm. Another study has demonstrated that the anterior maxilla can resorb by 23% in the first six months, and an additional 11% in the following five years. (Artzi 2000) The reason for this difference in the rate of resorption may be due to the differing width of the buccal plate in certain areas of the mouth. The relative dimension of the buccal wall has a direct reflection on the amount of bone loss. (Tomasi 2010) Consequently, the thinner the buccal plate, the more resorption of the buccal plate that occurs. In a study measuring the thickness of the buccal plate in the maxillary anterior region, it was found that close to 50 percent of subjects exhibited a thickness of less than 0.5 mm. (Januario 2011) A similar study found that about 87 % of maxillary anterior teeth exhibited a facial bone thickness of less than 1 mm. (Huynh-Ba et al., 2010) Another study with similar results showed that as a rule, the buccal bone wall is thinner than its palatal counterpart, greater than 70% of the buccal walls are less than 1mm thick, greater than 87% of buccal plates in the anterior region are less than 1mm, and greater than 64% of anterior buccal plates are less than 0.5mm. Only a small proportion (6.5%) of maxillary anterior teeth have a buccal plate thickness of 2mm or greater. Another study found that 97 percent of maxillary central incisors had a facial bone thickness of less than 2.0 mm at 1-5mm below the crestal bone. (Nowzari et al., 2010) Studies have shown that buccal plate thickness of at least 2mm is required to prevent resorption of the alveolar ridge. Other studies have shown that the facial bone thickness should ideally be 4 mm to ensure adequate support of the soft tissue, to prevent resorption of the buccal plate following restoration, and to achieve optimal esthetic results. (Grunder et al 2011) Therefore, most maxillary anterior sites will require additional augmentation (i.e GBR) to maintain adequate bony contours around the implant and achieve optimal esthetics. (Huynh-Ba et al., 2010; Spray et al., 2000)

MAXILLARY VERSUS MANDIBULAR SITES

Several studies have shown that bone characteristics such as composition and resorption rates vary between jaw sites. The rate of alveolar ridge resorption (extraction alone) has been shown to be greater in the mandible (0.4 mm/year) than the maxilla (0.1 mm/year). (Nemcovsky et.al., 1996) Other studies show the opposite with ridge preserved sites having resorption rates two to three times greater in the maxilla than mandible. (Poulias et al., 2013) Implant success varies between jaw sites and is likely related to differences in bone quality and quantity. The maxilla has been shown to consist of thinner cancellous or spongy bone and lower cancellous bone density. The mandible usually has a moderate to high cortical and cancellous bone composition, and rarely presents with insufficient height or width of bone. Implants placed in the maxilla have demonstrated a lower success rate (80-90%) than the mandible (over 95%) after 15 years. The highest implant success occurs in the anterior mandible, with a 10-year success rate of 98%. The maxilla has a higher chance of failure, with a 10-year success rate of 82% in the anterior. (Bryant et al., 1998)

Although there are studies showing anatomical specificity in regards to success rates of implants, other studies show no difference. In a prospective clinical trial assessing hard and soft tissue changes following extraction of maxillary and mandibular posterior teeth, similar vertical and horizontal resorption changes were observed. (Schropp et al, 2003) In another study comparing maxillary and mandibular sites, approximately 2.5 mm loss of ridge width occurred at both jaws, showing no significant difference between the two. (Leblebicioglu et. al, 2013)

Anatomical Factors Affecting Ridge Resorption

Anatomical factors and alveolar bony defects, such as facial bone thicknesses, dehiscences, and fenestrations may influence the rate of alveolar ridge resorption and contribute to complications to implant placement. In a study with human skulls, fenestrations and dehiscences were frequently found in maxillary first molars and mandibular canines, respectively. (Davies et al., 1974) Fenestrations were three times higher in the maxilla than mandible. Defects were common in areas of thin buccal bone due to tooth position and dental anatomy. (Elliott and Bowers, 1963) Significant alveolar ridge undercuts or concavity frequently exists in the maxillary anterior leading to fenestration at the time of implant placement. A narrow crestal ridge width frequently leads to dehiscence at the time of implant placement. (Poulias et al., 2013)

Summary

Alveolar bone loss occurs as a result of periodontal disease or following tooth extraction, complicating subsequent treatment and implant placement. Significant changes in the dimensions of the alveolar ridge occur following tooth loss, and the resulting loss of ridge height and width and requires a ridge preservation procedure to counteract this atrophy.

Bone quality and quantity are factors utilized by clinicians to assess primary stability and endosseous implant success. Numerous classification systems have been presented in the literature to assess bone quality and quantity, but none have been validated for any clinical applications. Many classification systems utilized today have deficiencies such as poor objectivity, reproducibility, and variations in bone quality and quantity characteristics. The Elian classification system is a system that purports to have clinical applicability and be utilized as a prognostic tool for future endosseous implant placement. However at present, there is no research validating the Elian classification system with respect to the level of retained alveolar bone at four months post extraction.

Ideally, treatment strategies designed to maintain bone or promote its formation would be based on knowledge of the underlying cell biology and regulation. At this time, our knowledge of these mechanisms is incomplete. In particular, whilst it is established that the use of membranes at extraction sites is beneficial with regards to bone preservation, the mechanisms involved are not fully delineated, and we lack a basis for the selection of the best types of membrane.

PURPOSE

The purpose of this study is to evaluate the validity of the Elian classification for predicting post-surgical outcome, and to determine if site-specific factors influence the outcome. Specifically, a retrospective *post hoc* sub-group analysis in the ongoing Buccal Overlay Grafting clinical trial will be performed to assess the Elian classification system as a useful tool in predicting the prognosis of an extraction site for future implant placement. Additionally, different variables will be analyzed to determine if site-specific factors such as the location of the extraction socket in the oral cavity (e.g., maxilla versus mandible) make a difference in the outcome assessment.

HYPOTHESES

HYPOTHESIS #1

It is hypothesized that the Elian classification will be a useful clinical tool to guide treatment planning for future implant placement by providing a significant correlation to clinical outcome.

HYPOTHESIS #2

It is hypothesized that the level of retained alveolar bone at four months post extraction will be independent of site-specific factors (i.e. maxilla *versus* mandible, posterior *versus* anterior).

SPECIFIC AIMS

AIM #1; ELIAN CLASSIFICATION SYSTEM VALIDATION

Determine if the Elian classification system can be useful as a clinical tool to guide treatment planning for future dental implant placement. Determine the relationship between the evaluated Elian classification value and the amount of bone present at the time of implant surgery. A post-hoc statistical analysis will be performed. A significant relationship would indicate a predictive value for the Elian classification system.

AIM #2; EFFECT OF ANATOMICAL LOCATION

Determine if the anatomical location of the dental implant has an influence on ridge preservation outcome. Statistical analyses will be performed to find a relationship between anatomic location and the amount of retained alveolar bone. For the retrospective, post-hoc subgroup analyses, the subgroups are anatomical location, (Anterior, Posterior), jaw site (Maxillary, Mandibular), and Elian classification value (type 1, type 2). The effect of anatomic location, jaw site, and Elian classification type on the amount of retained bone will be studied. No significant relationship between anatomic location, jaw site, and Elian classification type would indicate that all extraction sockets can be treated the same and with the same success.

MATERIALS AND METHODS

OVERVIEW

Study Population & Study Design

A retrospective *post hoc* analysis of treatment results from a clinical trial currently being conducted at Tingay Dental Clinic was carried out by examining CBCT data for the level of retained alveolar bone at four months post-extraction. This trial was designed as a randomized-controlled, double-blinded study of 2 years duration. IRB approval of the study protocol was obtained, and all participants signed an informed consent prior to the start of the study.

Two different barrier membrane materials, dPTFE (Cytoplast) and amniotic-tissue derived membrane (BioXclude) and two different techniques, with and without buccal overlay graft (FDBA 250-1,000μm particle size, OraGRAFT, LifeNet Health, Virginia Beach, VA), are being studied to determine if either provides superior ridge preservation following single tooth extraction. Patients are divided into four groups based on the two variables of grafting technique and membrane choice. Buccal overlay graft with bone will be assigned to half of the patient population, and the other half receiving no overlay graft. At the conclusion of the study, half of the patients will have received amniotic tissue membrane (BioXclude) membrane to protect the graft, and the other half will have received dPTFE (Cytoplast).

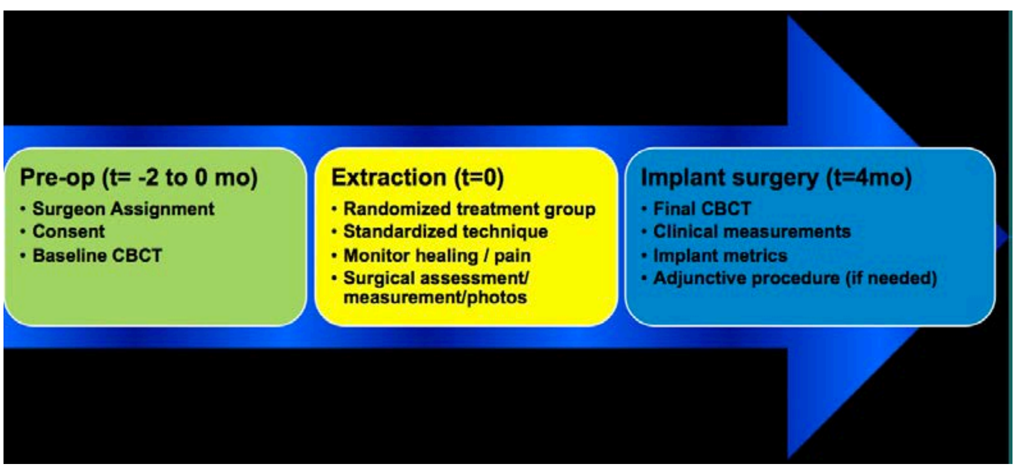


Figure 2: Clinical Study Design

Inclusion/Exclusion Criteria

In the ongoing clinical trial, single teeth that are treatment planned for extraction and ridge preservation were assessed. Inclusion criteria were any non-restorable tooth that could be replaced with an implant, and Elian type I and II sockets. Teeth with Elian type III sockets, teeth adjacent to implants without an adjoining tooth, teeth not replaceable with an implant, pregnant patients, third molars, patients with less than 4-months remaining in area were excluded. A total of 12 clinicians were utilized for extractions using a standardized technique.

Baseline and 4-months Post Extraction Measurements

Baseline and four-months post-extraction clinical measurements and CBCTs were taken. Tissue thickness, amount of keratinized gingiva, reason for extraction, presence or absence of infection, and anticipated Elian type were recorded at baseline. Difficulty of extraction, buccal plate thickness, total ridge width at crest, presence of dehiscences or fenestrations, anticipated and de facto Elian type, and ease of product use were measured during surgery.

In the present study, statistical analyses will be performed to find relationships between anatomic location, jaw site, and Elian classification type with the amount of retained alveolar bone. For the retrospective, post-hoc subgroups analyses reported here, the subgroups are anatomic location and Elian classification type. The effect of anatomic location (anterior, posterior), jaw site (maxillary, mandibular), and Elian classification type (type 1, type 2) on the amount of retained alveolar bone will be explored.

3-D Subtractive Radiography

Three-dimensional subtractive CT radiography was used to detect changes in ridge width, height, and surface area from the center of the ridge up to the first 4mm. Baseline and 4-

month CBCT images were reformatted into digital imaging and communications in Medicine (DICOM) formats and imported into viewing software (Dolphin Imaging Software) that allows for manipulation of multiplanar reconstructed slices and three-dimensional volume renderings.

HYPOTHESIS #1

Restatement of the Hypothesis

It is hypothesized that the Elian classification will be a useful clinical tool to guide treatment planning for future implant placement by providing a significant correlation to clinical outcome. Data from the ongoing clinical trial at Tingay Dental Clinic will be statistically analyzed.

HYPOTHESIS #2

Restatement of the Hypothesis

It is hypothesized that the level of retained alveolar bone at four months post extraction will be independent of site-specific factors (i.e. maxilla versus mandible, posterior versus anterior).

Detailed Methodology

Computer software and a professional statistician will be used to conduct statistical analysis of the data. Clinical parameters (anatomic location, jaw site, alveolar bone ridge height, width, and surface area measurements, Elian classification type) at baseline and at 4 months post-extraction or at the time of implant placement will be analyzed, and a correlation between the Elian classification type to prognostic application will be explored.

The outcome measures for this retrospective study were vertical height, horizontal width (at the level of the crest, 2-mm below, and 4-mm below crest), and surface area (total, 0-2-mm, and 2-4-mm below the crest) ridge dimensional changes. These values were calculated for both baseline (tooth extraction) and 4-months post-extraction.

Data points from each patient involved in the clinical trial were extrapolated to include the Elian classification type, membrane type utilized, follow-up times, outcome measurements, complications encountered, and any deviations during surgery.

DATA DESCRIPTION

Independent Variables

There are two categorical nominal independent variables for the clinical trial: membrane type, and buccal augmentation. Each independent variable has two levels, membrane type--dPTFE (Cytoplast) and Amniotic tissue membrane (BioXclude), and the use or disuse of buccal augmentation.

For the present study, there are three additional categorical nominal independent variables: Elian type (two levels, I or II), anatomical site (six levels representing combinations of anterior-posterior, maxilla-mandible, premolar-molar), and facial plate thickness.

Dependent Variables

The dependent variables are ridge width, height, —millimeter, and percentage changes from baseline (continuous), surface area changes in cubic millimeters, and implant placement success (categorical, nominal).

DATA ANALYSIS

Descriptive statistics will be prepared, including tests for normality of distributions. Multivariate ANOVA will be used for data analysis of bone changes. Fisher's exact test will be used for implant placement success data. A p value of 0.05 or less will be considered significant. Post-hoc testing will be conducted to determine which groups result in any significant effect.

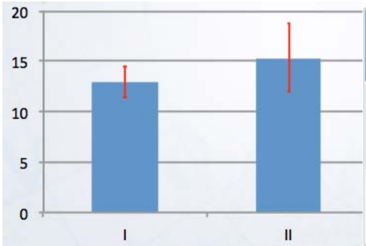
RESULTS

There were 100 patients with extraction sockets meeting the inclusion criteria enrolled, but only data from 48 patients were extrapolated. Fifteen patients were dis-enrolled due to poor quality of CBCT, poor compliance, or did not meet inclusion criteria. All sites were bordered by at least one tooth mesial and distal. There were 38 Elian I sockets, 9 Elian II sockets, 29 from the posterior maxilla, 18 from the posterior mandible. Out of the 85 patients where extractions were completed, clinicians were 91.49% accurate at correctly diagnosing the Elian classification type, 4.25% were underestimated, and 2.13% overestimated.

Data from the randomized clinical trial were analyzed via two-way ANOVA and found on average any one treatment (dPTFE, ACM membrane with or without buccal overlay graft) had the same resorption rate as any other treatment group. For the current study, the data were grouped together for two independent variables, Elian type and anatomic location. A statistician was not available for the current study and the data was analyzed via two-tail t-test. A total of 47 teeth were analyzed; 38 Elian type I sockets, 9 Elian type II sockets, 29 maxillary, 18 mandibular, 3 anterior, and 44 posterior teeth (15 premolars, 29 molars). There were a low number of anterior teeth enrolled because most patients opted for an immediate implant, therefore the anterior cases were excluded from the study.

Elian Type: Total Surface Area Changes

Total surface area changes within the first 4-mm of the ridge were measured, after which limited bone resorption occurred. Most bone resorption occurred in the vertical and buccal dimension within the first 2-mm of the ridge. The thirty-eight Elian type I sockets healed with an average loss of 12.95 mm^2 or 28 percent of the original ridge (range gain of 1.5 mm^2 to a loss of 36.3mm^2). The nine Elian type II sockets healed with an average loss of 15.32 mm^2 or 39 percent of the original ridge (range loss of 5.2mm^2 to a loss of 37.9mm^2). No statistical differences were found between Elian I and Elian II extraction sockets in terms of bone loss (see Table 1).

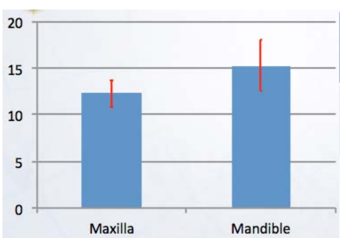


Elian Type	N	Mean Δ Area	SEM	Min Δ Area	Max Δ Area
I	38	-12.95 (-28%)	1.54	+1.5 (Gain)	-36.3 (-66%)
II	9	-15.32 (-39%)	3.34	-5.2	-37.9 (-80%)

Table 1: Total Surface Area Changes by Elian type

Anatomic Location: Total Surface Area Changes: Maxilla versus Mandible

Twenty-nine extraction sockets in the posterior maxilla healed with an average loss of 12.28 mm or 27 percent of the original ridge (range loss of 1.7mm^2 to 36.3mm^2). Eighteen extraction sockets in the posterior mandible healed with an average loss of 15.23 mm or 34 percent of the original ridge (range gain of 1.5 mm^2 to a loss of 37.9 mm^2). For both the maxilla and the mandible, mean surface area changes were found to be statistically similar with the posterior maxilla healing with the same amount of resorption as the mandible (see Table 2).

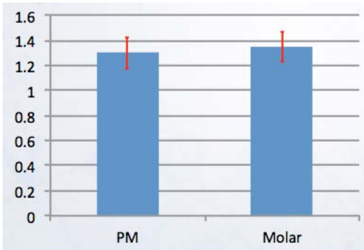


Anatomic Location	N	Mean Δ Area	SEM	Min Δ Area	Max Δ Area
Posterior Maxilla	29	-12.28 (27%)	1.48	-1.7 (Loss)	-36.3
Posterior Mandible	18	-15.23 (34%)	2.75	+1.5 (Gain)	-37.9

Table 2: Total Surface Area Changes by Anatomic Location

Anatomic Location: Facial Bone Thickness

Fifteen premolar extraction sockets had an average facial bone thickness of 1.3 mm (range 0.5mm to 2.0mm). Twenty-nine molar extraction sockets had an average facial bone thickness of 1.34mm (range 0.5mm to 2.5mm). No statistical differences were found between premolar and molar extraction sites (see Table 3).

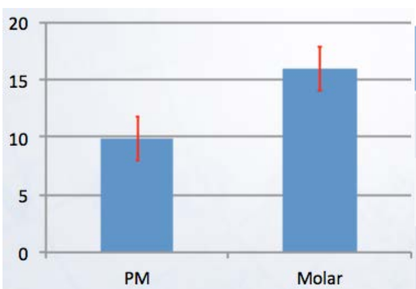


Anatomic Location	N	Thickness (mm)	SEM	Min	Max
Anterior	3	0.77	0.145	0.5	1.0
Premolar	15	1.30	0.127	0.5	2.0
Molar	29	1.34	0.122	0.5	2.5

Table 3: Facial Plate Thickness

Anatomic Location: Total Surface Area Changes: Premolar versus Molar Sites

Fifteen premolar extraction sockets healed with an average loss of $9.83mm^2$ or 25 percent of the original ridge. Twenty-nine molar extraction sockets healed with an average loss of $15.88mm^2$ or 33 percent of the original ridge. A statistical difference was found between premolar and molar sites (see Table 4).



Anatomic Location	N	Mean Δ Area	SEM	Min	Max
Anterior	3	-7.43 (22%)	1.612	-5.0	-10.5
Premolar	15	-9.83 (25%)	1.878	+1.5	-20.4
Molar	29	-15.88 (33%)	1.904	+1.0	-37.9

Table 4: Total Surface Area Changes Premolars versus Molar Sites

DISCUSSION

The primary goals of this retrospective study of a double-blinded randomized clinical study was to test the hypothesis that the Elian classification system can be a useful clinical tool to guide treatment planning for future implant placement as well as the level of retained alveolar bone at four months post extraction will be independent of site-specific factors. It was demonstrated from this retrospective study (which agrees with past studies) that bone loss whether its an extraction or ridge preservation site that bone loss occurs mainly on the buccal portion of crestal bone (the most coronal portion of the alveolar crest).

Specific Aim #1

In 2007, Elian reported that type I extraction sockets were the most predictable to treat with either an immediate implant or ridge preservation and an Elian type II extraction socket the most difficult to diagnose and that a bone graft and membrane is required before implant placement. This study proves Elian's claims that Elian type II sockets are the most difficult to diagnose with about 4.25 percent misdiagnosing (underestimating) an Elian II socket as an Elian I socket. We found, base on our data, that the Elian classification system is a very good universal communication tool that clinicians are about 91 percent accurate at diagnosing. Elian et al described treating Elian type I and type II extraction sockets differently but the current study contradicts that claim. Despite dehiscence and fenestrations or the presence or absence of the buccal bone, ridge preservation is still effective for implant placement with 100 percent primary stability achieved for all implants.

Specific Aim #2

There are anatomical, biological, and surgical factors associated with bone loss following tooth extraction including facial bone thickness, extractions socket size, dehiscence and fenestrations, physiological remodeling, surgical technique and experience. Alveolar ridge width and surface area changes in this study did not differ between the maxilla and the mandible. This contradicts previous studies where maxillary sites exhibited more bone loss than mandibular sites. A facial plate thickness of less than one millimeter is monocortical, lacks bone marrow and sufficient blood supply, leading to osteocyte death, and consequently atrophy of the surrounding mineralized bone. Research also tells us that thicker facial bone can better withstand resorption than thinner bone. Studies have also shown that the facial bone is thicker in premolar and molar sites than anterior sites. The current study has shown no significant differences in facial bone thickness of premolar and molar sites but despite that, molar sites resorbed more than premolar sites. One possible reason for more ridge resoption in molar sites could be the larger socket size in molars versus premolars. The dental literature has shown mixed results in the amount of ridge resorption based on jaw site (maxilla versus mandible), but the current study has shown no significant differences in bone resorption.

Limitations of this study include sample size and tooth type differences between jaws and location. Another potential limitation was surgical technique or experience. Within the limitations of this study, the results suggest the possibility that the amount of bone resorption following ridge preservation is independent of site-specific factors.

Possible future directions of this study could incorporate bone core biopsies for histologic analysis for amounts of percentage of mature bone, new bone, and graft material.

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