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Transplantation of a Bone Graft with a Tooth in Situ

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Loyola University Chicago

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TRANSPANTATION OF A BONE GRAFT
WITH A TOOTH IN SITU

BY

SAM PETER LIAROS

A Thesis submitted to the Faculty of the Graduate School
of Loyola University in Partial Fulfillment of
the Requirements for the Degree of
Master of Science

JUNE
1961
Sam Peter Liaros was born in Toledo, Ohio, September 25, 1929.

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CHAPTER I

INTRODUCTION

Literature reveals that a vast amount of work has been done on autogenous bone grafts and tooth transplantation. Although a great deal remains unknown about the behavior of these tissues.

Autogenous bone grafts have been used to repair defects in the mandible. Much has been done with transplantation of teeth. The implanted teeth have become functional due to an ankylosis of tooth and bone. The interruption of the immediate environment of the tooth results in eventual root resorption.

With the knowledge of tooth and bone transplantation, it was undertaken to transfer a compound osteodontic graft.

This paper will report the preliminary investigation of the surgical approaches in transplantation of a bone graft with a tooth in situ.
CHAPTER II

REVIEW OF THE LITERATURE

For this thesis a review of the related literature reveals that a similar investigation has not been undertaken previously, however, there are vast amounts of work done on bone grafts, and much has been done on tooth transplantation, especially in the past decade. The literature reviewed includes: (A) Transplantation of teeth; (B) Transplantation of Autogenous Bone Grafts. An attempt will be made to discuss the two topics in the above order, however, a certain amount of overlapping should be anticipated by the reader.

A. TRANSPLANTATION OF TEETH

To begin, a clarification of the terminology will be brought out so that the reader does not become confused, due to the terms used by authors having different connotations. A uniform terminology will help to facilitate communication in the various fields of dentistry.

Definition of terms:

Replantation - The act of replacing a tooth, with a vital or a nonvital pulp, in the same alveolar socket from which it had been removed either surgically or as a result of trauma.

Implantation - The act of embedding an artificial tooth
into the alveolar ridge.

Transplantation - The operation of transferring a tooth, one with a vital pulp or one having had root canal treatment, from one site to another in the same individual or from one individual to another.

Autogenous transplantation - The transplantation of tissue from one site to another in the same individual. Autogenous means self-originating or origin within itself. It is preferred over the term autologous which implies relation but not origin, which is of primary importance in regard to transplanted teeth. Therefore, autogenous transplantation is the plantation of a tooth to another site but in the same individual in whom the tooth was generated.

Homogenous transplantation - The transferral of a tooth from one individual to another individual of the same species.

Heterogenous transplantation - The transferral of a tooth from one species to a different species.

Transplanting and reimplanting teeth are as old as the profession of dentistry. An oral surgeon of note, Albucasis of Cordova, described a method for transplanting teeth back in the eleventh century.

For many years scientific publications have recorded
favorable clinical experiences with dental transplants.

In Central and South America early natives tried implantations. A Pan American Bulletin reports that in the ruins of excavations at Cacpan, a lower jaw was found with a lateral incisor that had been carved from some dark stone and implanted to take the place of a lost tooth.

Allen (1685) author of the first English Dental Book refers to "taking out the rotten teeth or stumps and putting in their place some sound ones drawn immediately out of some poor bodies head." This practice was considered as merely speculative.

Hunter (1775) is credited with being the first actual leader in transplantation and reimplantation experiments in animals. He stated, "there is a tenancy for all living substance to unite when brought into contact with one another. A tooth which has been extracted for some time, so as to lose the whole of its life...will never become firm and fixed." He transplanted healthy tooth into the vascular combs of roosters to preserve the life of the periodontal membrane for future use which constitutes in effect a "tooth bank." He contended that the periodontal membrane retained its vitality for periods up to as long as twenty-four hours, even though the tooth with its membrane attached was not in its natural
Garlette, Lemaire, Flagg and others soon after the American revolution led the fashion in transplanting teeth in America.

Owens (1862) experimented with the transplantation and adhesion into the combs of cocks and the establishment of a vascular connection between the tooth and comb.

Kostechka (1938) reported successful tooth transplants in animal studies. Lapchensky and Malinovsky (1941) reported the transplanting of developing tooth buds from puppies into the alveolar sockets of adult dogs. The fresh transplants were described as having grown to full size in their new positions. Also, the researchers recorded successful transplants had been accomplished by sacrificing the donor puppies on the day preceding the transplant procedure and storing the jaws of the sacrificed animals overnight in a refrigerator. Thus again the practicability of a tooth bank had been investigated.

Shapiro and McLean (1945) reported before the International Association of Dental Research, stated that, from their research animals, they had concluded that "intra-alveolar tooth germ transplants are capable of differentiating and persisting." Their studies dealt with the transplantation
of developing tooth germs in the mandibles of cats.

The average complete resorption of the roots of replanted teeth is approximately four years. The longest reported case of retention is quoted as nineteen years. It was reported by Kells, who believed that an ankylosis was formed between the root and the bone. Others have reported successful cases ranging from one to ten years.

Krueger (1953) states that resorption may be rapid or exceedingly slow. He reported a case that was functional for a period of eighteen years.

Durglass (1954) reported that the consensus is that the replanted tooth constitutes, in fact, a foreign body with a complete interruption of its circulation. A slowly progressing root resorption ensues, resulting in the roughening of the surface and development of a honeycombed appearance due to an osteoclastic attack on the denuded cemental surface of the root.

Ingle and Dow (1953) replanted central incisors with root canal therapy after total luxation. They observed an ankylosis with subsequent root resorption on the incisors. However, an average expectancy of seven years is altogether possible.

Miller (1953) stated that results in reimplantation of
teeth seem to be both good and bad. No definite procedure has yet been established nor enough cases and years behind it to justify any startling conclusions. More interest and clinical work will probably bring our outstanding developments.

Transplantation of unerupted third molars replacing first molars has been investigated by Miller (1954). Collings (1955) reimplanted a horizontally impacted second premolar. The unerupted tooth was removed with the follicle enveloping the tooth, and placed in an upright position. Post-operative follow up showed that the tooth was normal in every respect.

Miller (1956) in his research on transplantation and reimplantation of teeth indicated that the best suited tooth for transplantation is an unerupted third molar with uninjured developmental membrane. The crown should be well formed, because shortly after transplantation it is pushed up out of the socket by a calcifying blood clot which unites with the developmental membrane giving nourishment by osmosis. A tooth with a partly formed root may be replanted immediately without root canal therapy, but a mature tooth may require root canal therapy before reinsertion. He preformed thirty eight transplantations. Of these twenty were still in the
patient's mouths and offered a good prognosis. Nine were extracted or fell out. Nine are still in the mouth, but are becoming resorbed and do not seem to offer a favorable prognosis.

Waite (1956) conducted a study on the basis that it had been proven scientifically that the active vitality of tissue requires chemical activity which, in turn, depends on molecular movement. Also, that another requirement of chemical activity is the presence of water in the tissue. Therefore, he felt that, by removing water and lowering temperature it may be possible to preserve the tooth in storage for a longer period of time. He used four five month old puppies and completed the following operations.

1. Autogenous transplants
2. Homologous transplants
3. Extraction of tooth, elimination of pulp tissue, and replantation of the tooth.
4. The extracted teeth were exposed to glycerol, frozen in dry ice, rewarmed, and transplanted.
5. Extracted teeth were directly frozen in dry ice, rewarmed, and transplanted.

He noted the following conclusions: 1. Freezing techniques for tooth storage purposes should not be ruled out, but they
require further investigation; 2. Glycerol did not stand up to expectations, but it was evident that extracting water from the pulp prior to freezing was helpful; 3. The complete removal of the pulp has possibilities and, if successful, would alleviate the problem of pulp preservation in all prospective transplants; 4. Immediate autogenous transplants show good pulp preservation and are well tolerated by the host; 5. Root resorption on some of the transplants was noted. However, this was partially due to the difficulty in immobilizing the dogs teeth and keeping the animal from injuring it. Resorption is also believed to be due to granulation tissue, which was on the basis of infection.

Boyne (1957) used freeze-dried homogenous bone grafts in the surgical positioning of teeth. He indicated that when homogenous freeze-dried cancellous bone grafts are utilized in the positioning of adult impacted maxillary cuspids, an early clinical attachment or close apposition of the periodontal structures appears to occur, with the alveolar bone of the host apparently (as judged by roentgenographic examination), replacing the graft material with normal osseous tissue. It appears that the repositioned tooth becomes a useful healthy member of the dental arch. The procedure was a pilot study to gain some indication of the efficacy of
utilizing homoplastic osseus material in the application of the surgical positioning technic to adult dentition.

Kadaniov (1960) conducted a study including 280 teeth from 1945 until 1959, 139 of which are documented. Replantation is chiefly indicated in traumatic luxation of teeth. It can also be applied to cases of teeth with crooked root canals, the cleaning and filling of which is unsatisfactory. There are different opinions as to the method used. Great variety of medicines and root fillings are employed. Some men fix the replanted teeth, others do not fix them. The results of replantation are varying and replanted teeth have different duration. For the successful replantation of teeth and their duration the indications, as well as the method employed, are of great significance. The success and favorable prognosis of each surgical intervention and the replantation depend on the exact indication and the proper application of the method employed. According to the researcher, replantation is indicated, as a rule, in traumatic dislocation of the teeth and also in cases of many-rooted teeth as well as in others, with periodontitis and with gangrenous pulp, where therapeutic treatment is unsuccessful and apicoectomy cannot be applied. Replantation of teeth is contraindicated in roots of teeth, in destroyed alveoli, as well as in hemor-
rhagic diathesia, hemophilia, and lues. Kodankov’s method of replantation was in one sitting. In the surgical manipulation and the external treatment, he applied physiological saline solution, and in later years he used a 1-2% colloidal-electrolytic solution with a pH of 6.5-7.5 preserving the macroscopically healthy periodontium. After resection of the root apex, the root canals were filled with a silver or gutapercha point. The replanted tooth was fixed by a wire or combed splint, and during post-operative period antibiotics were administered. The results were encouraging. Of the cases documented the teeth are functionally quite fit. Radiographic examination established that there are no resorption changes. The success of the replantation depends upon: the preservation of the periodontium, treatment with antibiotics, and the good fixation of the replanted tooth.

Medical Academy of Lodz (1960) reported on an experimental series in which 943 extracted teeth were replanted. For a period of six years the replanted teeth were studied in 1,775 follow up examinations. Tooth replantation succeeded in 97.9%. The method consisted of replanting apically infected teeth after endodontic treatment. In all instances, the apical region of the alveoli had been surgically freed from granulation tissue. The teeth were replanted in their
own sockets without use of splints or other attachments. The success obtained was favorable compared with that achieved by using other methods such as apicoectomy, pulpectomy, or pulpotomy previously used to save the teeth. The disadvantage of tooth replantation is the gradual increase of failure as post-operative time advanced. The follow up examinations revealed yearly increase of failures. After a period of five years 41% proved to be failures. The number of failures, after a period of six years, could have been reduced if the proper indications for tooth replantation had been more carefully evaluated.

For this research a tooth will be transplanted without disturbing its immediate environment. To accomplish this, a graft from the mandible will be taken with the tooth in situ. Thus, a vital tooth will be transplanted, and the periodontal attachment will remain uninterrupted.

B. TRANSPLANTATION OF AUTOGENOUS BONE GRAFTS

Bone grafting has in all probability been practiced on man as a clinical procedure for about one hundred years. As an approved clinical procedure bone transplantation belongs to modern times. It is evident that although there has been much change in views and theories regarding the application of bone grafts in late years, still a great deal remains un-
known regarding the behavior of this tissue.

Nussbau (1875) recommended rotating a fragment still attached to the lower end so as to bridge a defect in the ulna, and fastened across a two inch defect in about the same way as the slide graft of present day use. Bircher (1886) of the University of Berne, found the inlay of intramedullary ivory pegs to be the simplest method of retention in fracture of the long bones. He also suggested the locking of fracture fragments with an I-shaped graft and reported good healing and consolidation in five cases of simple fracture.

Adamkiewicz (1889) came to the conclusion that small autogenous pieces of bone would reunite if they were replaced after removal by trephinning. He expressed the idea that osseus structures should come in contact but they need not fit accurately. He believed that the periosteum took no active part in the process of repair but that the cellular connective tissue which formed underwent ossification. He mentioned growth of bone proceeding from the periphery surrounding such bone transplants. In the case of ununited fracture of the tibia reported by Curtis (1892) there was destruction of bone with loss of substance. A segment of the patient's fibula was cut out and pushed through the soft tissue into the gap in the tibia. Firm union took place; weight bearing
on the limb was possible in two months after the operation. This was followed by four additional successful cases.

Murphy (1899) implanted the second phalanx from a patient with dactylism, in the nose as an autogenous graft. All periosteum and both of the cartilaginous ends were retained on the graft. In fourteen months the entire transplant disappeared. In 1901 he grafted the hypothenar eminence of the hand to the nasal bone, including the fifth metacarpal bone, by fixation of the hand to the head and noted that it retained its vitality.

Delayed callus formation relative to beginning pseudarthrosis was observed by Bier (1905). He regarded blood extravasation as the natural stimulus for callus; in addition, through excitation of inflammation, it brings about increased nourishment. Extravasation is a nutrient medium directly and indirectly because young cells of the callus probably consume it and apply it to bony structure. Extravasation, in his opinion, is necessary for healing of bone fracture.

Lexan (1908) decided that when autogenous bone grafts are transplanted with periosteum and endosteum the transplanted bone always dies but the periosteum and endosteum survive. The dead bone is later regenerated from the surviving periosteum and endosteum.
Vorschutz (1911) transferred an autogenous free graft from the tibia, covered with periosteum, to the region of the lower jaw which had been removed because of malignant tumor. After formation of a fistula and sequestration, healing occurred in the lower part. In another case in which the lower jaw had been resected because of actinomycosis, an autogenous piece from the tibia was transplanted. After five months bone could be palpated. Excellent cosmetic and functional results were obtained on both cases.

Carter (1911) transplanted autogenous rib, with the periosteum removed, into the nose in nine patients to repair saddle deformities. The medullary tissue was scraped from the outer half of the graft, and the skin and subcutaneous tissue over the dorsum and sides of the nose were elevated, as well as the periosteum over the nasofrontal process. The strip of bone was inserted into the wound in the nose, reaching nearly to the tip, and the upper part anchored under the periosteum over the nasofrontal process. There was no sign of the disappearance of the graft or any irritation at the end of four to eighteen months.

Hibbs (1911) who was a master technician, achieved a remarkably high percentage of good results in his bone grafting. After denuding the laminae of cortical bone and removing all
cartilage from the intervertebral joints, he used the spinous processes and the tiny bits of bone supplied by the denudation to fuse a diseased spine. He applied his method, with slight modifications, to fuse the hip, the knee, and other joints.

Murphy (1912) reported on his observations and analysis of microscopic photographs and pathologic specimens, clinical and experimental, by others. Bone with its periosteum, transplanted in soft tissue in the same individual and free from bony contact, practically always dies and is absorbed. Autogenous bone transplants, with or without periosteum, in contact with living bone become united to living fragments and act as a scaffolding for reproduction of new bone of the same size and shape as the transplanted bone. The role of the transplanted fragment is to give mechanical support to capillaries and blood vessels, with their living osteogenic cells, as they advance from the living bone at both ends of the implanted fragment into the haversian canals, canaliculi, and lacunae of the transplant. Ultimately all of the transplant disappears; new lamellae are formed by the osteoclasts, and the graft lamellae are removed by the osteoclasts. He concluded that the graft is per se not osteogenic but osteoconductive. The regenerative forces and cells are entirely supplied from the osteogenic cells which are nourished by the
capillaries growing from living bone. The graft, however, is an absolute necessity in the regeneration. Periosteum attached to the transplanted portion when taken from the young has a "plus osteogenic influence"; in the middle aged it is neutral, and in those of advanced years it plays a minor role and, in fact, is detrimental.

McWilliams (1912) transplanted a piece of autogenous rib, subperiosteally resected and separated from periosteum, into a lower jaw defect resulting from the removal of giant-cell sarcoma; it was successful after two months, healing by primary union. In another patient, autogenous rib was transplanted into the tissue of the inguinal hernia to strengthen the canal. Primary union also occurred. He has the idea of shaving bone in small pieces for transplantation, and he considered periosteum as having a very important function in maintaining the nutrition of the graft. In several of his cases where rib bone was stripped of periosteum and implanted in bony contact or in soft tissue, the graft disappeared. Clinically, when bone with periosteal covering was implanted, new bone formed along the periosteum of the graft. McWilliams believed that the callus arose from the periosteum or from the bone of the graft itself. To be assured of subsequent living of a bone graft, it should be transplanted with as
much periosteum covering its surfaces as possible.

Gallie and Robertson (1919) held that from a clinical standpoint the periosteum is of great importance because of its control of the circulation throughout living bone. Extensive stripping of the periosteum at operation will result in necrosis, which may cause delay in union and will result in sequestration where sepsis is present.

Albee, who wrote the first book published in any language on the sole subject of bone graft surgery, was a pioneer in introducing a method of bone grafting for Pott's disease of the spine. He believed that a bone graft always acts as a stimulus to osteogenesis in the bone into which it is engrafted or with which it is in contact. Survival is enhanced by exact approximation of the components of the graft with the same components of the host bone. He was convinced that the best transplant is a live piece of autogenous bone including periosteum, complete thickness of the cortex, endosteum, and marrow. Transplanted living bone tissue becomes a part of the osseous system wherever it has been implanted. Albee also used "sliver grafts" alongside the main fixation graft to furnish additional foci of bone growth.

Neuhof in 1923 expressed the belief that the liberation of substances from the slowly disintegrating graft consti-
tutes a physiochemical stimulus, resulting in the metaplastic formation of bone tissue from the adjacent host connective tissue. He further stated that the bone cells of the graft die more or less rapidly, depending upon their distance from the source of nourishment in the host, and the periosteum and endosteum undergo at least partial necrosis. However, primary adhesion to the host tissues occurs most readily in the presence of periosteum.

Lewin (1924) repaired a large fragmented wound in the left side of the skull with autogenous bone, including periosteal covering, from the fifth and sixth ribs of the same side. The margins of the ribs were "rawed" and the ends trimmed; the pericranium was stitched over the ribs, and the flap of the scalp replaced. The patient made an uninterrupted recovery, the cranial defect becoming filled in by a regular sheet of bone.

Baron (1926) successfully used the astralgus as the source of the transplant in operation on a child with pseudarthrosis following fracture of the shaft of both bones of the leg about four years previously. The conical ends of the tibial fragments were wedged in the transplant and the whole covered with a strip of periosteum removed from the other tibia. He held that spongy bone, combined with periosteum,
or with periosteum and cortex, is the best material for bone
transplants.

Matwejew (1930, from the Kasan-Levin Institute) used
bone plate from the tibia that had been implanted under the
skin of the left shoulder, to repair a nasal defect in a
thirty five year old man. Histologically, the implant showed
bone and cartilage tissue, and permeation with bone cells
interlaced with numerous haversian canals. The new bone was
thought to be differentiated in structure and character from
the implanted bone.

Carter (1930) considered the rib, with its outer later
of periosteum, as best suited for bone transplantation. He
used combined bone and cartilage transplant in repairing sad-
dle-nose deformity in which the nose is too short, the cart-
ilage end of the implant being introduced as far as the tip
of the nose without destroying its resiliency. In the case
reported there was increased growth of the transplant at
points of contact with the frontal and nasal bones two years
after operation.

In a case of myxochondroma metacarpi reported by Petrov
(1933), a proximal phalanx of the big toe from the left foot
was used for the defect produced by resection along with the
whole proximal part of the bone. There was complete change
in structure of the transplant twenty five years and nine months after the operation. The inner bony prominence remained, while the external one was absorbed.

Orell in 1937 expressed his belief that boiled fresh bone often has the proper shape and structure for replantation when bone is in a pathologic condition and other types of osseous grafts are not so applicable. In some instances he resected the diseased bone, boiled it, cleared it of diseased tissue masses and replanted it for mechanical support until new bone developed. Such boiled autogenous bone serves as a stimulant to living connective tissue in the bed. Boiled bone contains fat, connective tissue, and proteins. According to Orell, when boiled and dried bone is used for grafting, its resorption and the growth of new bone take place very slowly and much less satisfactorily than when boiled fresh bone is used.

In the opinion of Esmaurrizar (1940) of Mexico City, some transplanted living cells in living bone transplants may possibly continue to develop, but most of them disappear and are replaced by new cells derived from the surrounding tissues. He thought that the grafts have mechanical functions (sustaining and refilling), chemical functions (as a source of mineral salts in situ), morphological functions (the bone
canals serving as guides to the medullary cells, promoting the formation of new bone within the graft), and perhaps biological function, stimulating osteogenesis.

In a roentgenographic and biopsy study of autogenous human iliac bone grafts by Rainsford Mowlem in 1941, the survival of the bone cells and calcified structures of iliac bone grafts appeared to depend upon the nourishment which the graft receives after transfer rather than upon its contact with living bone. The cells in cancellous bone grafts will survive as living cells associated with calcified matrix when the graft is transplanted into a vascular bed whether or not it is in contact with bone. When cancellous iliac bone grafts are transplanted into an avascular bed, the cells in the graft die and the graft structure is replaced by fibrous tissue. It is Mowlem's belief that the cells in dense cortical bone grafts tend to die, even when they are transplanted into vascular beds, because of lack of early nutrition. He noted that iliac bone grafts not in contact with bone retained their calcified structure up to periods of one year but all of these grafts were transplanted into the nose; none were in soft tissue elsewhere, either vascular or avascular. Thus Mowlem's factual observations confirmed Carter's conclusions that the soft tissues of the nose constitute a
rather favorable transplantation site for bone grafts. At any rate the site is favorable for the survival of iliac and rib grafts.

Fragmentation of cancellous bone makes a greater proportion of its cells accessible to the blood supply and expedites its survival (Iowlem).

Blocker (1946) emphasized that autogenous tissues are generally used in the fresh form. Many congenital deformities and defects following trauma have been repaired by autogenous bone transplants, but not as successfully as had been hoped. The fact that a quantity of bone is accessible and is able to withstand strain has led to its popularity as a material for grafting. He described what happens grossly following bone transplantation in contact with bone as follows: healing following transplantation of bone occurs in much the same way as after primary fracture. A clot is organized in the graft bed and organizing vascular connective tissue invades at a rate which is in reverse proportion to the density of the graft. After the establishment of vascularization some bony absorption takes place, and finally calcium is redeposited and firm bony union results.

Most investigators believe that the graft is slowly replaced by a process of creeping substitution from elements
in the host or from its periosteum, but others, believe
that the bone cells under favorable conditions survive en
masse and retain the calcified structure of the graft.

Compact bone grafts are as a rule obtained from the
crest of the tibia, while those of cancellous bone generally
die and serve only as a trellis for the formation of new bone.
In a series of cases Flanagan and Burem (1947) obtained
union of defects in the tibia and femur by apposing massive
grafts, with supporting external cortex in the form of a cy-
linder and re-establishment of continuity of the medullary
canal. The massive grafts become integral parts of each
other as well as of the host itself, depending upon adequate
blood supply to the grafts and positive fixation of the grafts
internally.

Horwitz (1949) advocated the use of cancellous bone as
a graft to gridge or fill as ossous defect at the end of the
long bone, where spongy bone normally predominates. Cancell-
ous bone containing red marrow appears to have greater osteo-
genic properties than cancellous bone in which yellow marrow
predominates. The iliac wings consist of an enormous quan-
tity of red marrow.

Catalona (1951) reported a case of a compound fracture
of the middle third of the leg that had been treated else
where. Severe infection occurred, followed by drainage. Then the patient was seen, the leg was flail in the middle third, with dense scarring of the skin and so forth. In a Flanagan-Burem operation the scars were excised, and thick split-thickness grafts taken from the abdomen were applied. Three months later, an apposing hemicylindrical massive bone graft was used in reconstruction, following which osteogenesis and union were observed. At the end of a year the grafts were becoming an integral part of each other as well as of the host bone itself. The patient returned to work, without using a cane. Catalona pointed out that the intactness of the periosteum, the necessity of interfering with intermediary callus and sclerosing with intermediary callus and sclerosing bone ends, the need of internal fixation, the use of inlay, onlay, single or dual grafts and of cortical or cancellous bone graft, and the presence of infection, scar tissue and unhealthy skin should be carefully considered if healing is to be given an optimum chance to occur.

Axhausen (1951) stated that bone findings tend to show that in the death of bone a stronger stimulation to bone formation comes from the periosteum belonging to it. This stimulation is exerted forcefully, in particular on the mesenchymal tissue. The observation on transplants of autogenous
bone covered with periosteum agree with this finding. Autogenous bone covered with periosteum must maintain its commanding position in repairing large defects of the tubular bones and lower jaw, for the forces of osseous reconstruction lie within it.

Peer (1951) made a histological study of thirty-six autogenous bone grafts from rib, tibia, and ilium in contact with unlike tissues (soft tissues). The bone grafts whether cancellous or cortical, were replaced by fibrous tissue in eight to twelve months after transplantation, the bone cells of the graft disappearing when the matrix was absorbed. This occurred regardless of the presence or absence of periosteum on the grafts or their thickness or thinness. Bone grafts transplanted in the vascular tissue of the neck and in muscle were absorbed just as readily as when they were transplanted into the relatively avascular subcutaneous fat of the abdominal wall. His interpretation is that rib, tibial, and iliac bone grafts tend to lose their calcified matrix when they are transplanted into soft tissues regardless of the vascularity of the host bed.

Herndon and Chase (1954) reported the fate of autogenous and homogenous bone grafts including articular surfaces. Dogs were used as experimental animals and the knee joint was
selected for study. Histologic study of the fate of autogenous, delayed homogenous, and direct homogenous knee joint transplantations were as follows.

The meniscus and articular cartilage behave similarly in delayed homogenous and direct homogenous transplantations, but necrosis appears much earlier in the homogenous grafts than in the autogenous transfers, and repair is much slower and less effective.

The spongiosa became necrotic in all three types of grafts but orderly repair took place in the autogenous transplants with reorganization largely complete by nine months. In the direct and delayed homogenous grafts, only sporadic attempts at repair were present, with most of the spongiosa remaining necrotic even at twenty four months.

The cortical bone became necrotic in all three types of grafts and repair began in all at about thirty days. In the autogenous grafts, the reorganization progressed rapidly until it was complete at nine months while, in both the direct and delayed homogenous grafts, repair was much slower with many dead tracts remaining even at two years.

The marrow of the autogenous grafts was replaced rapidly by invading connective tissue which was transformed into normal yellow or red marrow by nine months. Although the necrotic
marrow in the direct and delayed homogenous grafts was replaced by invading cellular connective tissue, it was not transformed into yellow or red marrow except in small scattered areas even at two years.

Bony union in the step cut area occurred as rapidly in the delayed and direct homogenous grafts as in the autogenous.

Revascularization of the Haversian canals proceeded rapidly in all three types of grafts with the process being almost complete by the end of thirty days.

In the autogenous grafts, a few tracts in the cortical bone in the step cut area remained viable but most of the bone became necrotic. Reorganization appeared by thirty days and progressed orderly until completed at nine months. In both the direct and delayed homogenous grafts, all osteocytes became necrotic; and, although osteoclasis and osteogenesis were present by thirty days, repair was not complete until two years in the direct homogenous graft, and there were still a few dead tracts at two years in the delayed homogenous graft.

Hashop and Zeiss (1960) reported on the clinical success of homogenous and autogenous bone grafts. Procedures were performed on 137 autogenous and 143 merthiolate - preserved homogenous bone grafts. There were 12% failures in the autogenous group, 23% in the homogenous group, and 21% in the
group in which combination of autogenous and homogenous bone grafts were used.

The incidence of failures with autogenous chips was eight per-cent. When a full thickness autogenous bone block was used the incidence of failure was seventeen per-cent. The incidence of failure with homogenous chips was nineteen per-cent; when a full thickness block graft was used the incidence was thirty-one per-cent. A combination of autogenous and homogenous chips resulted in an eighteen per-cent failure.

Their clinical review confirmed the impression that autogenous grafts are superior to homogenous grafts. Homogenous bone grafts are satisfactory in specific situations, but they must be protected for a longer period of time than autogenous grafts. It is believed that homogenous bone is of greatest value in supplementary autogenous bone.

With the successful results of bone transplantations it was undertaken in this paper to transfer a mandibular bone graft with a tooth in situ.
CHAPTER III

MATERIALS AND METHODS

A. Subjects

Nineteen mongrel dogs were used in this investigation. They were divided unequally into five variable groups I, II, III, IV, and V. Only those dogs with a full complement of permanent teeth were used.

Due to their position and accessibility, the mandibular third premolars were selected for the surgical procedures. The maxillary third premolar also, was considered, but due to the proximity of the floor of the maxillary sinus to the apicies of the premolars in dogs, it was not selected.

B. Basic surgical technique applied to all mongrel dogs investigated.

The technique employed was basically the same in all the subjects except for variations in each of the five groups investigated.

Group I - Five dogs were used.

The first thing that was considered was the occlusion of the subject. The normal occlusion was observed and this brought our that the molar teeth and the anterior teeth were the only teeth that came into contact with the opposing arch.
The posterior teeth were to be the main support of the splint to be used. The cusps of the posterior teeth were reduced enough to take them out of occlusion and to compensate for the thickness of the splint to be placed over them. The anterior teeth were not reduced because the splint would not be placed over them. The four premolars did not occlude and there was sufficient intermaxillary space to accommodate for the thickness of the splint. Diamond dental burs were used to reduce the cusps.

Substantial and adequate stabilization is of prime importance in grafting. An appliance was developed which would fulfill the requisites such as 1) Adaptability 2) Strength 3) Simplicity 4) Ease of insertion 5) Facility of removal. For this a splinting appliance of acrylic was constructed. Impressions were taken with specially made trays which would properly fit the dog's mandible. Alginate impression material was used to take the impressions. Coecal stone was used to make the master models. The master models were studied, surveyed, and an outline of the splint was marked. The splints extended anteriorly from the cuspid, posteriorly to the distal of the first molar, buccally to the vestibule, and lingually to the floor of the mouth. The splints were reduced in the areas of the occlusal surfaces of the teeth to eliminate
any undue trauma to the splinted area during mastication. As an aid to the stabilization of the acrylic splint, holes were drilled at selected areas, so that it could be securely wired into place.

Anesthesia

The dogs were anesthetized with Nembutal Sodium 50/cc. One cc. was administered intraperitoneally, per each five pounds of body weight. A local anesthetic, Rovacaine hydrochloride with 1:60,000 epinephrine per cc. was administered. The epinephrine constricted the blood vessels in the operative site to decrease hemorrhage.

The instruments were autoclaved, the dogs were draped, and all aseptic techniques were observed.

Before beginning the surgery, a bite block was placed into the dog's mouth.

The incisions were made from the cuspid anteriorly to the first molar posteriorly along the gingival margins of both the buccal and lingual mucoperiosteum which allowed for a generous flap. The mucoperiosteum was reflected inferiorly to the muco-buccal fold on the buccal aspect and to the inferior border of the mandible on the lingual aspect.

Due to its position and accessibility, the third premolar was selected for the tooth bearing bone graft. With the muco-
periosteal flap reflected the mandible was exposed. Measurements and landmarks were made of the mandible to insure accurate cutting of the graft. Two oblique cuts were made, one of which coursed between the 2nd and 3rd premolars and the other between the 3rd and 4th premolars, and extended apically to the mandibular canal. One horizontal cut was made which was parallel and immediately superior to the mandibular canal.

The oblique cuts were made so that the base of the graft would be wider. This feature would aid in stabilization by preventing acclusal displacement of the compound graft.

By means of a 700 tapered fissured bur the buccal and lingual cortical plates of bone were penetrated. During the bone cutting a steady stream of saline solution was employed to decrease the amount of friction and heat created by the dental burs. The compound graft was completely disengaged from its bed and put in saline solution until the recipient site was prepared. The same procedure was repeated on the opposite side of the mandible. The donor site was sutured and left to heal.

The recipient site with the compound graft in position was treated as follows. The mucoperiosteum was approximated very carefully and interrupted sutures were placed interden-
tally along the entire length of the incision. Surgical cement (Wards Wonderpak) was applied to the wound and molded around the teeth. The acrylic splint which was constructed pre-operatively, was placed over the dressing.

Twenty three gauge stainless steel wire was passed through the holes of the splint. The anterior of the splint was wired to the canine tooth and the posterior was wired by passing the wire between the first and second premolar teeth.

Immediately following the operative procedure the dogs were infected intramuscularly with 600,000 units of long acting Bicillin as a prophylactic measure to guard against infection. The dogs were given soft diets, which consisted of Red Heart dog food with water, to decrease trauma during mastication. The diets were supplemented with vitamins A, D, E, C in daily minimum requirement doses.

Group II - Five dogs were used.

The technique employed was the same as in Group I except for one variation. The acrylic splint was not pre-made as it had been in Group I, instead, it was made after suturing and application of surgical cement to the wound. The self cure acrylic, which was mixed and molded over the surgical cement, extended from the cuspid anteriorly to the mesial of the second molar posteriorly, to the mucobuccal
fold buccally and to the floor of the mouth lingually.

This was done so that the acrylic, in its doughy stage, could be forced into the undercut area of the teeth and the lingual plate of the mandible. The feature of the undercut would maintain the splint in a stable position. To prevent the setting of the acrylic, which is due to a chemical reaction that is exothermic in nature, it was flooded with saline solution. This eliminated the inflammation of the tissues contacting the acrylic during its initial setting time.

Group III - Four dogs were used.

The basic technique employed was the same with several variations. One of the variations involved the cutting of the bone. Lightening discs and chisels were substituted for the tapered fissured burs.

By utilizing these lightening discs the diastema of the actual cut was decreased. Prior to cutting, the donor and receipient sites were measured with a millimeter ruler to make them identical in width and depth. Compensation, for the width of the cuts made by the discs, was made at the receipient site so that the donor's graft would fit tightly in the transfer site. The graft being well approximated is an important factor effecting bony union of the parts.

Another variation was the changing of the splinting
appliance employed in Groups I and II. Cast crowns, for the second premolar and the first molar, were made from models prepared by the same procedure used for Groups I and II. Orthodontic wire in the form of filligree was placed between the crowns and soldered to them. The wire, extending from the crowns, was placed along the buccal and lingual aspects of the premolar teeth to avoid displacement of the compound graft. To aid in locking the graft in a fixed position, the appliance was cemented to place, and acrylic was used over the filligree wires in the area of the transfer site.

Group IV - Four dogs were used.

The basic technique employed was the same except for the following variations.

At the start of surgery two circumferential wires were introduced by means of a twenty three guage needle. The wires were passed through the buccal mucosa, at the inferior border of the mandible, to the lingual mucosa. One wire was in the area of the first molar and the other the first premolar. When surgery was completed the splinting appliance was made as in Group II. While the initial setting of the self-curing acrylic was taking place the circumferential wires were tightened so that they would be included in the splint.
Group V - One dog was utilized.

The basic technique employed was the same with one variation. The lingual mucoperiosteum was not reflected from the mandible but, instead, was left intact. This was done for the purpose of vascularization to the graft site. The splinting appliance for this group was the same as that introduced in Group IV.

Specimens

The nineteen mongrel dogs were sacrificed at prearranged dates from twenty four hours to three months in longevity. To sacrifice the dogs 50mg/cc. of Nembutal Sodium was administered into the heart. Twice the amount of the drug was injected for sacrifice as was for anesthesia.

To remove the specimen the lower lip, cheeks and floor of the mouth was resected. Care was taken not to disturb the graft and the surrounding tissues. The mandible was cut with a Gigly saw between the first and second premolars and the third and fourth premolars. The specimen was immediately put into ten per cent formalin.

Specimens were fixed in ten per cent formalin. Ten per cent nitric acid in formalin was used as a decalcifying agent, because its penetration is rapid thus preventing excessive action of the acid on the soft tissue. The spec-
imens were embedded in paraffin, and sectioned at six microns and stained with hematoxilin and eosin.
CHAPTER IV

FINDINGS

A. CLINICAL OBSERVATIONS

Gross observations and evaluations were made on the nineteen dogs used for the surgical approaches. The dogs were visited daily for clinical evaluation.

1. Group I

The dogs were sacrificed at intervals of twenty-four hours, seventy-two hours, one week, two weeks and one month.

a. The twenty-four and seventy-two hour dogs postoperatively had submaxillary and buccal swelling. The acrylic appliance and dressing were removed. The mucoperiosteum about the compound graft was not attached to the mandibular bone. The soft tissues showed inflammation.

b. The one week specimen was the same, with the addition of pocket formation and no signs of reattachment of the mucoperiosteum about the bone of the graft. Also, the splint was loose indicating that the graft was not completely stabilized.

c. The two week specimen showed that the splinting appliance was completely loose. The mucoperiosteum was not reattached and the bone of the graft was denuded. The wound
was infected and showed signs of chronic inflammation. The blood clot was absent in the area of the two vertical cuts.

1. The one month specimen was sacrificed and when examined the acrylic appliance was absent. The compound graft had been completely exfoliated indicating that a repair process had not taken place. Chronic inflammation was present at the graft site. The mucoperiosteum had become necrotic and the mandible which surrounded the graft was exposed.

2. Group II

The dogs were sacrificed at the same intervals as was done in the first group.

Clinical findings were the same in this group, except that the one month dog still retained the compound graft, because of the interosseus wiring technique used.

3. Group III

The dogs were sacrificed at intervals of one week, two weeks, one month, and two months.

a. The one week and two week specimens were the same as the first two groups.

b. In the one month specimen the splint was removed and the tooth in situ came out with it. This indicated that there was a degeneration of the periodontal tissues.

c. The two month specimen was the same as the one
month dog, except that the stabilizing appliance had become loose.

4. Group IV

The dogs were sacrificed at intervals of one week, two weeks, one month, and two months.

a. The one week and two week specimens were the same as the other groups.

b. The one month specimen showed that the splinting appliance with the circumferential wires was very stable. When the appliance was removed the tooth was observed to be very loosely attached to the alveolus of the bone graft. The bone graft proper was tested for mobility and it was found to be slightly mobile, indicating that healing had not taken place.

c. The two month specimen was clinically the same as the one month specimen.

5. Group V

The dog was anesthetized six weeks post-operatively and the splinting appliance removed. The mucoperiosteum on the buccal aspect had reattached itself and appeared to be normal. There was only very slight gingival recession present about the compound graft site. The tooth was found to be firmly attached in its alveolar socket. The bone graft
proper was tested for mobility and was found to be immobile. The dog was continued on a soft mush diet, in order to eliminate any undue trauma to the graft site.

At three months the dog was sacrificed. At this time clinical evaluation of the compound graft site was made. The tooth was securely attached in the alveolar socket, and the bone graft proper was immobile. The soft tissues around the operated site appeared normal and healthy.

B. MICROSCOPIC EVALUATION

At twenty four hours a blood clot had formed. The cut surfaces of the graft and the recipient site are in close apposition with the blood clot intervening. The osteocytes are necrotic in the cortical and spongy bone at the cut surfaces both of the graft and recipient site. Polymorphonuclear leucocytes infiltrate the blood clot, and the endosteum and Haversian canals of the recipient site.

The pulp shows swelling of the odontoblasts and the reserve connective tissue cells. The nuclei of such cells appear dark blue with hemotoxilin and eosin stain. The periodontal ligament appears intact and normal.

At forty eight hours, the blood clot is degenerating in the presence of an abcess. The osteocytes in the cortex of the graft show necrosis not only at the cut surfaces but also
beneath the periosteum and along the periodontal surfaces. There are few surviving osteocytes in the interradicular bone of the graft. The pulp shows infiltration with polymorphonuclear leucocytes, pyknosis of the nuclei both in the odontoblasts and reserve connective tissue cells. In the periodontal ligament, the fibroblasts show pyknotic nuclei. The collagenous fibers appear normally oriented however, few polymorphonuclear leucocytes have now infiltrated between the fibers.

The recipient bone shows necrosis of the osteocytes at the cut surfaces. Proliferation of the loose connective tissue in the marrow spaces is evident. Osteoclasts in Howship's lacunae are resorbing the trabeculae of bone adjacent to the cut surface. Also, osteoblasts an apposing bone trabeculae of spongy bone.

At seven days both the cortical and interradicular cancellous bone are necrotic as the osteocytes are either absent or pyknotic. An abscess persists at the junction of the implant with the recipient bone. The pulp of the tooth is necrotic and shows polymorphonuclear leucocyte infiltration and suppuration. The cellular elements of the pulp are necrosed as seen by karyolysis of odontoblasts and reserve connective tissue cells. In the periodontal ligament, foci of poly-
morphonuclear leucocytes are seen. The collagenous fiber bundles are pale and swollen but appear to remain attached at the cemental and alveolar bone surfaces.

The recipient bone shows infiltration by polymorphonuclear leucocytes and plasma cells. Proliferation of loose connective tissue continues within the marrow spaces. Osteoclastic activity is evident as resorption of the trabeculae of bone adjacent to the cut surface continues. Osteoblastic activity is found in the marrow spaces increasing the thickness of the trabeculae.

At one month, polymorphonuclear leucocytes infiltration is dense between the graft and the recipient site bone. Such cells are seen to infiltrate the Haversian canals, interradicular spongy bone, pulp of the teeth and periodontium. Also, the immediate marrow of the recipient site also shows polymorphonuclear leucocyte infiltration. The resorption and apposition of trabeculae of the recipient bone is evident.

At three months, the bone and pulp of the tooth are necrosed. The periodontal ligament shows polymorphonuclear leucocyte cell infiltration. The fibers are pale staining swollen and broken. However, some fibers appear normally oriented between the cementum of the root and the alveolar bone surface. There is granulation tissue, plasma cells at
the junction between the graft and the implant site. Notably, bone apposition is seen on the recipient bone surface adjacent the granulation tissue intervening between the recipient site and the graft.

At six months, the graft is necrotic. The cortical bone shows empty lacunae. The pulp of the tooth is completely necrotic. The periodontal ligament fibers are pale staining, swollen and detached along the alveolar bone surface. Polymorphonuclear leucocytes infiltrate the periodontal ligament space. There is however, apposition of bone upon the trabeculae of interradicular spongy bone. This is the first evidence of organic union between the graft and recipient site bone. There continues to be apposition of bone on the trabeculae of the spongy bone at the recipient site. Also, there is subperiosteal apposition of bone on the surface of the mandible of the host.

C. RADIOGRAPHIC INTERPRETATION

At three and six months, radiographic interpretation of the specimens showed a breakdown of the periodontal membrane, radiopacity of the interdental bone where the vertical cuts were made and callus formation at the inferior border of the mandible.
CHAPTER V

DISCUSSION

In the transplantation of a bone graft with a tooth in situ many problems arose. It must be remembered that this is a compound graft which consists of a vital tooth and bone.

Various techniques which were employed in the surgical approaches presented special problems: In stripping the thin mucoperiosteum care must be exercised so as not to tear or rip the tissue due to its delicate consistency. The best method found to reflect the mucoperiosteum was to incise the gingival mucosa and periosteum to the bone surface of the mandible. To begin the initial reflection of the mucoperiosteum a very sharp periosteal elevator must be carefully inserted at the incision site, the mucoperiosteum may be very gently and gradually reflected. Once the entire length of the incision had been started the flap stripped away from the bone with ease.

In making the vertical cuts in the bone tapered fissure burs and discs were employed. The surgical fissure burs cut away so much bone tissue from the graft that it fit loosely in the recipient bone site. In order to minimize the amount of bone tissue loss, the diamond and lighting discs were
found satisfactory. It is important to keep a steady and constant stream of saline flowing to prevent the bone from heating excessively. The odor of burning bone indicated that the heat generated by the horizontal cuts created a great deal of trauma to both the graft and host. The Gigly saw was difficult to manage and, furthermore, the cuts were not straight, due to the inability of completely controlling and guiding the instrument.

The employment of a 700 tapered fissure bur for cutting bone was found to be most satisfactory. At a slow speed and with a constant stream of saline solution flowing on the bone being cut, it did not cause excessive friction or heat, most important the amount of bone cut away was minimal.

Stabilization of the compound graft created several problems. An acrylic appliance was constructed on models made from impressions taken of the animals mandible. The splints were constructed so that they would extend from the canine to the molar teeth. Holes were drilled at both ends of the lingual and buccal aspects so that it could be wired to the teeth for stabilization. The splinting appliance was not satisfactory, because it caused luxation of the teeth on which it was anchored, especially the canine, and also it created trauma to the surrounding tissues of the teeth. The wires
would become loose and cause the splint to dislodge itself. Much of this was due to the animals constantly causing injury to themselves and the splinting appliance in the course of mastication and by biting on hard substances, such as the wire cages in which they were housed. In order to minimize trauma to the teeth and surrounding tissues created by the wires, the splinting appliance was changed. Rather than making the splint prior to surgery it was made after closure of the wound, so that it could be molded into the undercuts of the teeth and the lingual plate of the mandible. The feature of the undercut would maintain the splint in a stable position, and the use of wires would be eliminated. It was observed that there was little of no undercut areas on the teeth due to their conically shaped crowns, which again caused dislodgement of the splinting appliance.

To prevent dislodgement of the splint a bridge-like appliance was constructed. Cast crowns were made for the premolar and molar teeth which were joined by filligree loops. The splint was cemented to place and self cure acrylic was molded into the filligree wires to stabilize the tooth and bone graft. The use of the splint proved inadequate as the dogs gnawed it and caused its dislodgement.

The employment of a splinting appliance made of self
cure acrylic after closure of the wound and the introduction of circumferential wiring proved successful. The wires were tightened and included in the splint after the acrylic had been molded over the graft site. The acrylic splint with circumferential wires was the best method employed. The graft was firmly stabilized; and the splint was not dislodged, and there was no evidence of trauma to the supporting tissues and teeth. I believe that this type of splinting appliance is the best method employed in stabilizing the tooth bearing bone graft.

The bone graft was mostly cortical bone. Cortical bone has a slower rate of revascularization of the Haversian canals as opposed to the layer of marrow spaces in spongy bone. Such failure of revascularization presents danger of secondary infection as the bone has lost its capacity to resist bacteria. The stripping away of mucoperiosteum from cortical bone in this type of graft is not practical, as the cortical bone comprises all of the labia and lingual plates. Only the interradicular bone is spongy. In group five of the experiment autopsy of the specimen showed repair of the interradicular spongy bone. This was also evidenced in radiographic interpretation. When the vertical cuts in the bone were made, it was observed that the cut itself was in close proximity to the
tooth to be transplanted. Frequently the upper third of the root surface was exposed injuring the periodontal ligament. In future experiments I believe that the employment of a larger section of bone be utilized in order not to expose the root surfaces.

In cutting out the tooth bearing bone graft the blood supply to the tooth was disturbed. Although the pulp was vital as the tooth was transplanted it did not survive. The pulp underwent degeneration and subsequently became necrotic. Consequently, the viability of the tooth was lost. I believe that in further investigation the teeth should receive root canal treatment prior to or during the surgical procedures. This procedure should serve to eliminate the problem of pulp necrosis.

The periodontal ligament was not disturbed except in the coronal third of the root. It was observed that it underwent degeneration and ultimately necrosis. Due to the breakdown of the periodontal fibers the tooth would become loose in the socket and eventually exfoliate. In autopsy specimens the tooth in the bone graft could be lifted out of its socket.

The donor and recipient sites were both measured and were cut equally in length, width, and depth. The bone of the implant site was smoothed out with the use of files and rov-
geurs and care was exercised so that an adequate vascular bed was established. In preparation of the implant site the graft was measured and this measurement was used to prepare the recipient site. The employment of this method created a better approximation of the graft and the implant site.
CHAPTER VI

SUMMARY AND CONCLUSION

The preliminary investigation of the surgical approaches in transplantation of a bone graft with a tooth in situ was performed on nineteen dogs.

The same basic surgical technique applied to all the animals investigated, except for variations that were made in the osteotomy and the method of construction of the splints.

The cutting of the bone presented problems which was solved by the utilization of 700 tapered fissure burs for preparing the vertical and horizontal cuts. This method proved most satisfactory, in that, destruction of bone and trauma were minimized.

Immobilizing the graft with the use of splinting appliances and the stabilization of it presented difficulties. Various modifications were made until a satisfactory result was obtained. The utilization of self-cure acrylic molded over the operation site after closure of the wound immobilized the compound graft securely, and the circumferential wires incorporated in the acrylic prevented dislodgement.

The major portion of the bone graft was cortical bone
which does not revascularize well and undergoes necrosis with poor repair. In future experiments the shaving away of a portion of the cortical bone is recommended. The vertical cuts made interdentally were in close proximity to the upper one-third of the root and frequently the bone cut away would denude the root. The employment of a larger block of bone would be recommended for future experiments.

The transferring of the tooth in the bone graft resulted in necrosis of the pulp of all of the nineteen dogs investigated. In future investigations of this nature root canal treatment is recommended prior or during osteotomy.

The periodontal ligament showed inflammation, degeneration, and necrosis. When the autopsy specimens were examined macroscopically the teeth could be lifted out of their sockets.

The implant site was made smaller to compensate for bone loss due to cutting of the donor graft. Thus, when the graft was transferred to the implant site it was well approximated.
FIGURE I

MUCOPERIOSTEUM REFLECTED SHOWING GRAFT CUTS IN THE MANDIBLE OF SPECIMEN
FIGURE II

SPECIMEN OF TOOTH BEARING BONE GRAFT AFTER REMOVAL FROM JAWBONE
FIGURE III
MANDIBLE AFTER REMOVAL OF TOOTH BEARING BONE GRAFT
FIGURE IV

GRAFT IN IMPLANT SITE
FIGURE V

CLOSURE OF WOUND
FIGURE VI

SPACING APPLIANCE
FIGURE VII

AUTOPSY SPECIMEN
FIGURE VIII

RADIOGRAPH SHOWING CALLUS FORMATION
FIGURE IX

RADIOGRAPH SHOWING BONE GRAFT WITH TOOTH
FIGURE X
MICROPHOTOGRAPH OF BONE GRAFT AND TOOTH
FIGURE XI

MICROPHOTOGRAPH OF NECROTIC PULP
FIGURE XII

MICROPHOTOGRAPH OF NECROTIC PULP AND PERIODONTIUM
FIGURE XIII

MICROPHOTOGRAPH OF PERIODONTIUM
FIGURE XIV

MICROPHOTOGRAPH OF DONOR GRAFT AND HOST BONE
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This thesis submitted by Dr. Sam P. Liacos has been read and approved by three members of the Department of Anatomy and Oral Biology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

5/31/61

[Signature]

Date

Signature of Advisor