A tripodal mandibular subperiosteal dental implant is a three piece cast metal framework that fits on the residual ridge beneath the periosteum and provides support for a dental prosthesis by means of posts or other mechanisms protruding through the oral mucosa. This implant is indicated in patients with advanced atrophy of the mandible where the unstable alveolar bone has completely disappeared, leaving in place the more stable basal bone with specific anatomical contours. The authors present their experience of 317 cases carried out in three different centers related to this implant modality and underline the importance of the basic anatomic, physiologic, and medical knowledge required to optimize the results.

INTRODUCTION

The mandibular tripodal subperiosteal implant (TSI) was originally conceived in 1984. It is a subperiosteal mandibular implant designed as a modality of choice for the oral rehabilitation of the edentulous patient presenting severe atrophy of the mandible. The surgical protocol is comprised of a two-stage surgery, the first of which results in taking a direct bone impression and the second in placing the custom-made implant. In the first stage of this surgical protocol, an alternative surgical approach to the classic full-arch bone exposure may be introduced. This consists of tree isolated segmental incisions and the bone impression taken in a multiphasic consecutive manner that avoids the dissection and injury of the inferior alveolar nerve prior to impression taking. The implant design provides for optimal support from the stable zones of the mandible, while avoiding the unstable zones, and for the conception of a compatible flexibility pattern. This design reestablishes the normal anatomic contours of the mandible and contributes to the harmonization of the stomatognathic apparatus. The long-term maintenance of the TSI is limited to the surveillance and management of the soft tissue around the distal abutments. A total of 317 TSIs have been placed by the authors at three different centers since 1984. Four implants had to be removed, and a number of mid- and long-term revisions were successfully dealt with by soft tissue management and structural modifications. This pa-
per presents a comprehensive study of the basic sciences and clinical and surgical knowledge necessary for this surgical protocol.

**GENERAL CONSIDERATIONS**

**Definition**

The TSI is designed exclusively for the advanced atrophy of the edentulous mandible, where the inferior alveolar nerve (IAN) is frequently situated in a vulnerable position, contraindicating the direct insertion of endosseous implants (Fig 1). The TSI, as its name suggests, is comprised of two posterior ramus frameworks or feet interconnected to an anterior symphyseal framework or foot by a flexible bar (Fig 2). Each foot is a subperiosteal structure that takes its support from the corresponding stable bony landmarks. These landmarks are, posteriorly, the external oblique ridge and its extensions laterally over the buccal surface of the ramus and lingually over the adjacent anterior surfaces including the retro-molar fossa, and anteriorly, the symphysis with its anterior extension over the labial surface of the symphysis medial to the mental foramina and its lingual extensions over the surfaces of the diagastric fossae that lie lateral to the genial tubercles.

**Anatomy and physiology of the mandible**

The mandible is a unique, dynamic, deformable, and three-dimensional suspended bone of the craniofacial system. Its form and function depend on the resultant synergy of the muscles, ligaments, and tendons attached to it. As such, it changes in form during its physiologic cycles (mastication, phonation, swallowing, yawning, etc).

**Anatomic Considerations Related to Subperiosteal Implantology**

**Symphyseal region of the mandible.** This is the converging point of the two hemi-mandibles. The clinical symphysis is limited laterally by the two mental foramina and frequently by the terminal endosseous trajectory of the loop of the alveolar nerve canal. The great stability of symphyseal osseous volume is essentially related to the intense mechanical activity that is transferred to it by the alternate tension-compression forces on each surface and segment of it. These forces are particularly synergized at the level of the genial tubercles and the diagastric of sublingual fossae, which present smooth, concave, and highly cortical surfaces (Fig 3a, b, c).

**Angular region of the mandible.** Four
anatomic landmarks in this region are of special interest in TSI surgery. The external oblique ridge, which is a round, convex continuation of the sharp-edged border of the coronoid process, takes its origin at the middle of the ramus. Its descent follows an anterior direction, while its convexity decreases until it is entirely blended with the lateral surface of the body of the mandible. The external oblique ridge receives the inferior fibers of the temporal muscle. Its densely cortical nature remains highly stable, and it is therefore considered the most resistant bone structure capable of supporting the metal framework of the TSI (Fig 4). The soft tissue covering the external
oblique ridge is inconsistent in its behavior—it may have very loose attachments on the top of the ridge or it may simply camouflage the ridge without any precise indication of the underlying bone (Fig 5).4,5

The buccal surface of the angle, which is a crescent-shaped surface about 15–20 mm between the concave and convex sides and approximately 35 mm in length, has its anterior concavity bordering the external oblique ridge. The inferioposterior side of the crescent is immediately in contact with the terminal fibers of the masseter muscle and is covered by a relatively thick periosteum. This surface continues with the adjacent surface of the angle in an infero-internal direction. The facial artery and vein intimately flank the posterior convex aspect of this surface and may present surgical hazards at the time of dissection. This buccal surface of the angle is also a stable bone and is therefore used as the extension area for the metal framework (Fig 6).

The anterior surface of the angle, which is a concave surface, is situated between the external and internal oblique ridges and presents a densely cortical and stable zone on its one-third to one-half buccal aspect (Fig 4, purple). It is covered by a loosely defined lateral soft tissue. The retromolar fatty pad situated anterior and lingual to the external oblique ridge, however, is the essential anatomical landmark of the distal mandible. This pad is a triangle about 12–15 mm long and 7–10 mm wide at its distal base. It has been described by one of the authors in 1989 to present, in a nonresorbed alveolar crest, a buccal side located inside a keratinized sulcus that is attached to the underlying alveolar bone near the internal oblique ridge, a lingual side that is partially without osseous attachments, and an anterior summit that rests on top of the crest within the third molar region. In advanced atrophy of the mandible, however, where the alveolar bone is near the internal oblique ridge, a lingual side that is partially without osseous void, through which runs the lingual nerve.

The internal oblique ridge, which represents the superio-internal border of the distal alveolar bone, is the anterior continuation of the inner "bifurcation" of the coronoid process (Fig 4, orange). It is often confused with the mylohyoid ridge, which is situated 3–7 mm below and lingual to it in an atrophied mandible. The mylohyoid ridge is a continuation of the median spine of the lingula and corresponds approximately to the internal surface of the mandibular canal in its ramus trajectory. However, the physiologic resorption of the internal oblique ridge accelerated by the loss of teeth may lower this ridge to a much closer relationship with the mylohyoid ridge, giving the impression that the floor of the mouth extends over the distal crest. The internal oblique ridge made of unstable alveolar bone should be systematically avoided with regard to the design and support of the implant.

Neurovascular Trajectory

The inferior alveolar neurovascular bundle runs along the lingual side of the ramus to enter the body of the mandible (Fig 7). It eventually crosses over buccally in the region of the first molar to continue anteriorly slightly buccal and parallel to the center of the atrophied residual ridge (Fig 8). This bundle exits through the mental foramina, which is located on the buccal aspect of the mandible. The mental foramina, however, may frequently have a crestal or even lingual orientation in advanced mandibular atrophy. It may also be accompanied by the one or more accessory foramina in different positions.

Physiologic considerations related to subperiosteal implantology

Alveolar Bone Resorption

Alveolar bone is a trabecular type of bone found exclusively in the maxilla and the mandible. It is the main osseous structure of the alveolar sockets in which the dental roots are lodged. It is therefore a highly specific and vascularized bone adapted to coexisting with the neighboring periodontal elements. It also has an intense response mechanism to the physical and chemical modification of the intra-osseous
TRIPODAL MANDIBULAR SUBPERIOSTEAL IMPLANT

The mandible is a deformable bone of the head, capable of various complex movements, of which two are of interest in implantology. These are corporal and ramus deformations. The nature and magnitude of the corporal deformation that takes place within the body of the mandible around centers and axes of rotation in the vicinity of the bicuspid are of great importance to implant and reconstructive treatment planning. The mandibular flexion (ramus flexion) is, however, the most important physiologic deformation of this bone, which has conditioned the design of the tripodal implant (Figs 10, 11).

**Mandibular Deformation**

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**Mandibular Flexion**

Mandibular flexion is the deformation of the mandible resulting from the opening of the jaws during normal physiologic functions such as speaking, masticating, etc, bringing the two rami closer together. In other words, there is a reduction of the distance separating the two condylar heads according to the frontal or axial planes going through them. This deformation takes its maximum amplitude when the jaws are at their maximum opening (3–5 mm at the level of the head of the condyles, 300–1000 microns at the level of the mandibular angle, and 100–300 microns at the bicuspid level). These variations may be in relation to the synergy of the pterygoid muscles, the elasticity of the mandible, and the size of the glenoid fossae.5,7 The mandibular flexion may cause variable degrees of discomfort and complications in patients who have been equipped with excessively rigid implant systems or prosthetic frameworks. These vary from mild discomfort upon normal
FIGURE 9. The diagram shows the normal variable rate of bone resorption, even in perfectly healthy situations, and the more extensive bone resorption that occurs after extractions.

FIGURE 10. The mandibular flexion (ramus flexion) plays a very important role in the tripodal subperiosteal design because of its inward and outward movements, especially at the level of the condyles during opening and closing of the mouth.

FIGURE 11. Shown is a pure titanium tripodal implant over the stone model.

FIGURE 12. Shown is a 12-year postoperative case after the center of the mesobar was cut less than 2 weeks after insertion because of a tightness in the rami when the patient opened her mouth. It immediately relieved her symptoms.

FIGURES 13–15. Incisions are made along the center of the anterior surface of both rami, and the tissues are reflected over the external oblique ridges and down buccally to expose a major portion of the buccal surfaces of both rami. Lingually, the tissues are reflected slightly lingual to the internal oblique ridges. Anteriorly, the symphysis is exposed down the symphysis menti labially, the genial tubercle superiorly, and the digastric fossae lingually, making certain to remain anterior to the mental neurovascular bundles.
functions of the mouth, to actual pain while opening it widely, to soft and hard tissue inflation and saucerization and possible fracture of the implants and prosthetics. In these situations, it is sometimes necessary to cut through the center of the anterior mesobar to give more independent movement of both sides of the implant (Fig 12).

Anatomy and histophysiology of the periosteum

The periosteum or periosteal membrane is a continuous composite fibroelastic covering membrane of the bone to which it is intimately linked. Although the bone cortex is the main beneficiary of the principal anatomical and physiological functions of the periosteal membrane, the behavior of the entire bone remains closely influenced by periosteal activity. These principal functions are related to the cortical blood supply, osteogenesis, and muscle and ligament attachments. Through its elastic and contractile nature, it participates in the maintenance of bone shape and plays an important role in metabolic ionic exchange and physiologic distribution of electrochemical potential difference across its membranous structure. It has also been suggested that the periosteum may have its own specific proprioceptive property.\(^5,8\)

Thus, the periosteum has been shown to contribute six functions: (1) providing the blood supply to the underlying bone cortex, (2) aiding the osteogenic activity of its cambium layer, tending to repair the underlying bone, (3) acting as an indispensable electrochemical potential difference barrier of the bone surfaces, (4) acting as a “protective” fibroelastic covering membrane of the bone, (5) (thus) maintaining the bone shape, and (6) being an important intermediary attachment of many muscles and ligaments to the bone and, as such, has an important biomechanical role. Most of the muscles of the craniofacial structures get their insertions on the periosteum and then fan out. Only a few muscles—such as the anterior insertions of the temporalis, which insert over the external oblique ridge and part of the anterior surface, and most of the stylus muscles (which go through the periosteum)—have a direct action on the bone.

Preoperative Considerations

Medical screening

Implant and preprosthetic surgeries aim to restore normal anatomical contours, function, comfort, esthetics, and oral health. As such, they are not lifesaving procedures. The prime concern must therefore be not to undermine the patient’s overall health and safety. It is only then that every step must be taken to maximize the longevity of the implanted system, including the overlying prosthetics. In the domain of subperiosteal implants over advanced bone atrophy of the mandible, the body response to implanted devices seems to be much less dramatic than to endosseous devices.\(^9\)

The cortical histoarchitecture and metabolism are far less affected by organ disorders than endosseous structures or grafted sites. However, the golden standard must be not to plan any form of implant surgery on patients who do not fall into ASA1 or ASA2 categories of the American Society of Anesthesiology. This can best be done by a thorough preoperative patient interrogation. Ten absolute contraindications must be noted: (1) recent myocardial infarction (less than one year or at least six months after stabilization), (2) valvular prosthesis (less than 18 months or at least 6 months after stabilization), (3) severe renal disorder, (4) treatment-resistant osteomalacia, (5) generalized secondary osteoporosis, (6) treatment-resistant diabetes, (7) radiotherapy in progress, (8) chronic or severe alcoholism, (9) severe hormone deficiency, and (10) drug addiction. To this list may be added heavy smokers (more than 20 cigarettes per day).

Patient screening must also take into consideration relative contraindications, where the doctor’s judgment will be the decisive factor as to whether these conditions can be imposed to eliminate risk factors. These relative contraindications are: (1) heavy smoking, (2) acquired immunodeficiency syndrome—seropositive cases, (3) pro-

Biologic Profile

A series of standard primary laboratory tests (SMA, PATTT, platelet count, CBC, calcimia, glycemia, hemoglobin, and calciuria) will be completed by additional tests if any significant organ disorder is suspected.

Imaging

Diagnostic-quality radiographs, including panoramic, lateral view cephalometric, and increasingly frequent CT scans with mandibular 3D reconstructions, are required to determine the relative bone volume, density, and intermaxillary relationship.

Oral Health

Visual and physical examinations of the oral cavity and head and neck region are performed to rule out the presence of tumors, lymphadonopathy, and mucosal pathosis. The quantity and quality of keratinized tissue in the areas where permucosal posts will be located are assessed to determine the need for soft tissue grafting to improve deficiencies prior to implant surgery.

Psychological Evaluation

There are many reasons patients seek implant therapy. It must be borne in mind that the reasons or factors motivating the patient to seek treatment are not always disclosed by the patient, and their expectations of treatment benefits may not be at all realistic. Psychosis or severe neurosis may preclude treatment in the otherwise qualified patient.

Volumetric Evaluation of the Residual Bone

Particular attention is given to the load-bearing areas of the symphysis and posterior mandible and rami relative to cortical bone mass and density. Postmenopausal women should be evaluated for estrogen and progesterone levels in an effort to stabilize osteoporotic conditions.

Preoperative treatment plan

Diagnostic Casts

Diagnostic casts are made to establish a preliminary plan as to the positioning of the implant and occlusal plane.

Occlusal Considerations

Prior to treatment, the proper vertical dimension and interarch relationship must be established and recorded, with the objective of restoring the patient’s natural and normal plane of occlusion to the one that existed when fully dentate.

Stage One Surgery

Subperiosteal surgery is carried out using mostly local anesthesia, or under intravenous sedation prior to local or block anesthesia. Occasionally, general anesthesia may be administered.

Incision and dissection of the mandible

A preoperative exploration of the mandible and its covering of oral and extra oral soft tissues is essential to determine the most favorable incision sites as well as their orientations. These orientations are a function of the quality and volume of the keratinized tissues, their locations, and underlying osseous anatomical landmarks. Furthermore, the exploration allows a more precise manipulation of the scalpel at the time of incision and periosteal elevators at the time of dissection.

For the interrupted incision technique, three isolated incisions are made: two in the rami and one in the symphyseal region. For each ramus, an incision is made along the center of the anterior surface halfway between the external and internal oblique ridges, starting about 5 mm below the coronoid neck and extending anteriorly to end where the ramus blends in with the posterior body of the mandible.

The tissue is reflected over the exter-
FIGURES 18–20. After the trays are trimmed and painted with adhesive material, they are placed inside (one at a time) with rubber-base impression material in it and held in place over each bony landmark until all three are taken, leaving them in position.

FIGURE 21. The same material (in this case, rubber base) is used to fill up a stock tray, which is held in position until it completely sets.

FIGURE 22. The tray is removed, and the three isolated impressions should come out with it.

FIGURE 23. Fast-setting plaster in a loose state should be carefully molded over the entire labial and buccal surfaces of the impression to support it prior to pouring on the master stone model.

The Tripodal Subperiosteal Implant braces the weakest part of the mandible.
nal oblique ridge and downward along the buccal surface of the ramus, which includes reflecting the inferior fibers of the temporalis muscles and the mas- seter fascia. Lingually, the tissue is reflected to the internal oblique ridge and is restricted from going lingual to it. Anteriorly, a midline labial vertical incision is made as well as an incision along the crest medial to each mental neurovascular bundle. The tissues are reflected so that the digastric fossae are exposed without releasing the tissues over the genial tubercles (Figs 13–15). A heavy-bodied putty impression ma- terial, placed over the concave anterior surface of the ramus and molded to conform to the buccal surface lateral to the external tissue, is the instrument of choice, while a second periosteal elevator as well as the fingers apply the impression material downward and over the lateral surface of the ramus. The impression material is stabilized by guiding the patient into a centric rel- ationship. The transfer of an extra oral pressure by massaging the cheeks im- proves this adaptation. A permanent mild pressure is applied over the entire impression to prevent it from being ex- pelled as the patient opens his/her mouth.

This procedure is repeated for the opposing distal site and the symphy- seal region, and as each impression sets, it is removed (Fig 16). Rapidly, a mix of fast-setting plaster of paris is mixed and poured into each individual heavy-bodied moldable polyvinyl si- loxane. When the plaster hardens, each one is removed from each impression. The hardened cast is placed beneath a vacuum-formed clear acrylic 0.08 sur- gical sheet, and using an Omnicat ma- chine, all three individual trays are then heated and stamped out over them. Tiny holes are made through each tray, and all overhanging and undercut areas of the trays are relieved. The undercuts that will cover the di- gastric fossae, however, are never re- moved from the trays (Fig 17).

Adhesive coatings are painted along the inside of each tray for further ad- hesion of the medium-bodied polysulfdie rubber-base impression material or light-bodied polyvinyl siloxane ma- terial that will be used for the final three isolated impressions.

Each tray is then filled with one of these materials and held in position over each bone segment until it completely sets (Figs 18–20). Allowing the impression material to flow beyond the peripheral borders of each tray is perfect-ly permissible at this time, as it will ensure stability and immovability of the impression while the operator dup- licates the procedure in the other two bony sites. These impressions must not be removed until they are picked up with the final impression tray. The three impressions are carefully linked together, using a stock tray or a cus- tom-made tray taken from the original soft tissue, with the same material that was used inside the segmental trays (Fig 21).

The entire impression composed of the three segments is removed when hardened (Fig 22). A soft mix of fast- setting plaster is carefully placed along the entire buccal and labial surfaces of the impression to support it from dis- torting while the master stone model is poured (Fig 23). At this stage, the val- ues of centric occlusion and vertical di- mensions are reconfirmed. This may be achieved through a number of procedures. A roll of heavy silicone paste is placed over the entire tray before it is removed, guiding the patient into a centric relationship and vertical dimen- sion, or, after the three bone impres- sions are picked up with a full-tray im- pression, a roll of heavy silicone ma- terial is placed over the exposed bone and soft tissue in between the bony ex- posures, guiding the patient into a cor- rect vertical dimension and centric oc- clusion.

An alternate technique consists of using the patient’s lower denture for the final bone impression.

The dentures are luted together properly prior to the surgery with self- curing acrylic along the buccal poste- rior surfaces of the teeth to hold the occlusion.

An incision and reflection of the mu- coperiosteal tissues to expose the un- derlying bone are then completed. Me- dium-bodied polysulfide rubber-base impression is molded over the exposed mandible. The tissue-bearing surface of the mandibular denture, after being prepared by shortening its flanges and painting on an adhesive, is also fitted with a medium-bodied rubber impres- sion material.

Both dentures luted together are then inserted into the mouth, and the lower jaw is moved upward toward the base of the lower denture. While the patient’s jaw is in centric occlusion, a cheek massage from the outside is done to roll the impression material around the periphery of the mandibu- lar denture base.

The laboratory procedures are fol- lowed by the immediate pouring up of the master stone model, and the artic- ulations of both dentures are brought to an articulator.

Refractory models are produced; the implant framework is waxed onto it, invested, and then cast and polished. The lower denture is then adapted to the metallic implant framework.

Both dentures are then polished, the implant is passivated, and they are re-

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**Figure 24.** The TSI transmits the forces of mastication from the teeth (14 to 16 teeth) to the skull while supporting the fragile mandible. In contrast, six endosseous root-form implants placed in the symphysis with two cantilevers on each side (10 teeth) cannot transmit these occlusal forces to the skull. Also, 70% of the occlusal loads are directed over the cantilevers.

**Figure 25.** (a) A diagrammatic sketch showing the fracturing of a severely atrophied mandible when the anterior-posterior spread to the cantilevered length ratios are exceeded. (b) An x-ray with two fractures in the mandible just distal to the last implants on each side.
turned to the doctor inside an autoclavable pouch ready for sterilization and insertion.

The implant is inserted during the second surgery, with the properly articulated dentures delivered at the same time.

The ideal timeframe between both surgeries is between three and four weeks.

**Soft tissue closure**

Before closing the soft tissues, the entire exposed bone and tissue surfaces are meticulously examined to eliminate any possible tray debris or impression material retained within the fibers of the wound. This may be further completed by gentle rinsing using an isotonic saline solution and immediately suctioning. Special care must be taken to repair any tissue tear that may have occurred by excessive retraction or at the time of tray and impression material insertion. The soft tissues are then sutured passively after precisely approximating the edges. A gentle but firm digital compression over the wounds using humid gauze for at least three minutes prevents the onset of a postoperative subperiosteal hematoma.

To minimize the trauma to the soft tissue, the patient whenever possible should refrain from wearing his/her lower denture for at least three or four days. The provisional denture prior to delivering it to the patient should be hollowed out on its tissue-bearing surface to its maximum and then relined with the soft tissue conditioner such as Visco gel, eliminating any contact with the soft tissue.

**Postoperative surveillance**

As no direct bone incision has been made, the postoperative care is essentially limited to facilitating an uneventful primary healing of the sutured soft tissues and protecting the reorganization of the underlying perioseal membrane during this transitory phase. It is therefore advisable to use a well-adapted antibiotic, a nonsteroid anti-inflammatory, and a peripheral analgesic, and an antiseptic mouthwash is to be used from the second day. Other drugs may include: (1) a corticosteroid injected locally around the soft tissues immediately after the surgery, which, in addition to its decisive anti-inflammatory action, may accelerate the onset of the periosteal repair by stimulating its osteogenic layer; (2) an equal dose of the same corticosteroid intravenously at the same time, and (3) a vitamin B complex for 48 hours to enhance the relief of pain (neurotonic and central nerve protection analgesic).

**DESIGN AND PROCESSING OF THE IMPLANT AND PROSTHESIS**

**Fabrication of the master model and analysis of the articulation**

The clinical profile indicates the TSI as the treatment of choice when complete resorption of the posterior alveolar process, with dehiscence or near dehiscence of the mental foramina and partial or total exposure of the IAN has occurred. Mandibular vertical height can measure as little as 4 mm in the body and 6 mm in the symphysis. The genial tubercles often project 1 cm or more above the symphysis and are frequently the most superior anatomic landmark anteriorly.

Transference of a major portion of the occlusal masticatory forces to the retromolar region is accomplished with the TSI. Functional occlusal force to the weakened atrophic body of the mandible is greatly reduced, which decreases the potential for pathologic fracture at, or distal to, the mental foramen. This qualifies the TSI as a viable and predictable treatment option when treating severe mandibular atrophy (Fig 24a).

In those cases where bone may be sufficient in the symphysis region to place interferominal endosseous implants to secure a removable posterior tissue-borne overdenture prosthesis (TBOP), the presence of dehiscent inferior alveolar canals and exposed mental neurovascular bundles prohibits this option. The placement of five or six root-form implants interforaminal-ly and the construction of a rigid, screw attached, distal cantilevered prosthesis (DCP) in these severely atrophic cases may not be a practical or predictable alternative to a TBOP to avoid direct pressure to the exposed IAN (Fig 24b).

Complex occlusal loading characteristics that can only be routed through the body of the mandible for dissipation are introduced. When distal cantilever length is smited, an abbreviated restoration may result in a lack of functional capability.

There are other functional limitations of fixed distal cantilevered units because of anterior-posterior (A-P) spread limitations. If recommended A-P spread to cantilevered length ratios are exceeded, the risk of fracture to a severely atrophied body of the mandible is a predictable possibility (Fig 25a, b).

Since these restorations are limited to providing only one-half of the natural posterior dentition, frequent occlusal equilibration is often required, and temporomandibular joint dysfunction may occur due to lack of sufficient posterior occlusion.

Studies on the occlusal force distribution of cantilevered prostheses, as recommended by Branemark et al, have been conducted. These studies demonstrated that as high as 70% of the occlusal forces were borne by the bilateral cantilevered units, and only 30% of the occlusal load was borne by the anterior segment and the supporting osseoindegrated fixtures when occluding with a full upper denture (Fig 24b).

For the treatment of severe to extreme atrophic mandibles, the TSI transfers the majority of these potentially destructive loads to the dense cortical bone of the retromolar area and the ramus utilizing a completely implant-supported prosthesis affixed to a rigid stress-distributing mesostructure (Fig 26a-d).

With the TSI, adequate bone volume is essential to support occlusal force...
per unit area of load-bearing surface. The faciolingual width of the anterior mandible must be adequate to support load-bearing struts for sufficient surface area to accommodate occlusal forces without exceeding the load-bearing capacity of the underlying bone.

Arch form and arch length affect the relative load distribution between the anterior and posterior load-bearing areas.

Arch Form

Mandibles with a square arch form are particularly suited to subperiosteal reconstruction with shared A-P load distribution characteristics. When the square arch form is restored with multiple root forms and a distal cantilevered prosthesis, in cases where adequate bone volume is present, the implants must be placed in nearly a straight line, which seriously limits the A-P spread. If the 1.5/1.0 A-P spread ratio is exceeded in an attempt to acquire sufficient posterior occlusion to be functionally beneficial, load magnification occurs through a class one lever effect. This causes excessive force concentration where it is least desired, at the mental foramen area, creating a serious potential for iatrogenically induced pathologic fracture of the weak body of the mandible in severely atrophic cases.

Admittedly, the term “square arch form” sounds contradictory; however, in the US, standard dental nomenclature designates variations in alveolar arch morphology as square, triangular, and ovoid.

Arch Length

Arch lengths are variable; however, relative A-P loads can be controlled and held fairly constant by design of the mesostructure. The anterior and posterior (ramus) load-bearing segments of the TSI are connected with a “rectangular beam placed on edge” configured mesostructure. According to the mechanical principle known as the Law of Beams, when the vertical dimension of a rigid beam is doubled, its arch length, or in cases with extreme resorption, very narrow buccolingual
dimensions, poor bone density or when defects of the body of the mandible are encountered, increasing the vertical dimension of the mesostructure will maintain rigidity of the mesostructure (Fig 27a, b).

**Design of the implant**

**Biomechanical Considerations and Implant Design**

Biomechanical factors related to mandibular anatomy favor the TSI to achieve the goals of providing a functional dental restoration, improvement in speech and mastication, improvement of the improved subperiosteal structure (Fig 27a, b).

**Rationale**

The tripodal concept is a logical evolution of the improved subperiosteal implant design based on histologic studies. The anterior and lateral aspects of the ramus with their increased fibrous attachments and significant hypertrophy of the dense cortical bone are utilized as major load-bearing landmarks, providing predictable posterior support. Sagittal cross-sections through the center of the symphysis at the level of genial tubercles (for the genial muscles) and coronal slices through the retromolar triangle (for the masseter muscle) show the direct correlation between the cortical hypertrophy and muscular traction on those areas (Figs 28, 29).

Smith et al reported a study of 49 dried, intact adult mandibles. Each mandible was cut cross-sectionally in three specific locations perpendicular to the sagittal plane of the body, ramus, and the occlusal plane. Cortical bone thickness was measured at the external oblique ridge and 5 mm above the inferior border of the mandible. The buccal and lingual cortices were found to be significantly thicker at the external oblique ridge than at the inferior border. The thickness of the buccal cortical plates in the retromolar region at the external oblique ridge measured 3.4 mm + 0.7 and 3.0 mm + 1.2 in the tree sections of the retromolar areas studied. The lingual cortical plates at the superior border measured 2.3 mm + 0.6, and 2.3 mm + 1.0 in the same respective sections. The lateral medial thickness of the mandible at the point in the retromolar area where the posterior load-bearing posts are usually located on a TSI measured 11.65–16.9 mm, with a mean of 14.9-mm width in this study (Fig 30). This indicates the densest bone in the posterior supporting permcuscal implant post sites. Therefore, a well-designed TSI can utilize the dense, thick, cortical bone of the retromolar area and distribute occlusal forces through the placement of secondary struts, linking the posterior prosthetic load-bearing post to the peripheral struts in a “snow shoe-like” arrangement. It is imperative that the ramus exit bar and post is located just slightly buccal to the internal oblique ridge, in both the lateral medial and A-P respect in the implant’s ramus segment relative to the retromolar triangle to fully utilize the densest bone of the ramus. If the bar is placed too high or too low, the occlusal loads will not be equally distributed when exiting the ramus.

The TSI design differs from the full subperiosteal implant in that the anterior load-bearing segment is not connected to the posterior or ramus segments by a continuous strut. The special mesomeasure with its rectangular beam placed on edge configuration imparts rigidity to the implant by preventing vertical flexure between the anterior and posterior segments; the entire load is shunted to the ramus via the special mesomeasure in the tripodal design (Fig 31).

An ideal ramus exit bar, to fully utilize all of the “snow shoe” bracing and the densest bone of the ramus, must not concentrate occlusal forces at either extreme end of the implant’s posterior segment. Force vectors should radiate in a deltoidal fashion away from the focus point of the exit site in a balanced pattern. The distribution of forces over a large surface area is feasible without impingement on muscles or vital structures.

The peripheral and secondary struts of the TSI provide retention of the implant by bracing against the widest and densest areas of the existing bone along the symphysis and buccal aspect of the ramus. When the implant is seated in place, it is braced laterally against the medial aspect of the external oblique ridge in the retromolar region and posteriorly against the anterior aspect of the ascending ramus. As the anterior segment is seated, the undercuts of the sublingual fossa are engaged by the lingual anterior permcuscal strut, which is the only undercut area used that presents anterior dislodgment, thereby virtually locking the implant in place. When properly designed, fabricated, and seated, retention is absolute. In certain cases, where the anatomical configuration of the symphysis may lack sufficient height to afford adequate retention, a bone screw can be used to prevent vertical movement during initial healing (Fig 32). The situation is most frequently encountered in the prognathic mandible, where labiolingual dimensions are often minimal and vertical surfaces are nearly parallel in the labial lingual aspect.

Although the tripodal design is resistant to flexure on a vertical plane, the opposite is true on a horizontal plane, where a degree of flexure is required. Torsional flexure appears to be accommodated through the relative vertical and horizontal limits.

The right and left anterior permcuscal posts are joined with a lighter gauge, curved segment that will allow for flexure of the mandible. Medial closure of the intragional dimension ranging from 200–1500 microns occurs from tension of the medial
According to the Law of Beams, when the vertical dimension of a rigid beam is doubled, its resistance to vertical deflection is increased by a factor of four or five. (b) The panoramic x-ray reveals the doubling of both posterior bars of the implant to increase vertical deflection (it was originally fabricated too thin).

Cross-sectional studies through the center of the symphysis and through the retromolar triangles have shown the extreme bone density of these areas due to the strong pulling of the muscular attachments.

Smith et al. reported a study of 49 dried, intact adult mandibles in which they confirmed the viability of using the anterior and buccal surfaces of the rami as posterior implant sites.

The TSI differs from the earlier subperiosteal implants in that the anterior segment load bearing is not connected to the posterior or ramus segments by a continuous strut. Also, force vectors should radiate in a delta-like fashion away from all focus points of the exit site in a balanced pattern.

Occasionally, when not enough bone prevails in the symphyseal area or when there has not been enough surface area along the dygastric fossae, bone screws may be introduced.
and lateral pterygoid and, to a lesser extent, the mylohyoid muscles when the jaws are opened to a maximum degree, as in yawning. If insufficient flexibility is present in the middle portion of the mesostructure, the medial gonial deflection rate of the mandible exceeds that of the posterior portion of the implant and a patient can experience pain when opening wide. Correction of the problem is sometimes accomplished by disking through the mesostructure, from the lingual side at the midline, to allow medial flexure of the implant at a rate compatible with that of the jaw. The patient will experience immediate relief of these symptoms.

**Choice of Prosthetic Supporting Bar**

A great percentage of full lower TSIs done today have a removable prosthesis. In choosing a retention system, we must look for a passive fit. Many types of retention systems, such as cast clasps, internal clips, Lew attachments, magnet, and screws, have been tried.
but the most popular system that meets the above criteria and the most requested system to date is the O-ring system. Large and small O-ring posts today are standard sizes used since the early '70s. Third generation surgical grade receptacles are cured into denture bases that house Food and Drug Administration (FDA)-approved O-rings (Figs 36–38).

Every type of occlusal scheme known to dentistry has been used on implant dentures. Considerations for maximum longevity of TSIIs include an efficient, self-balancing occlusion with the ability to unload the occlusion at night. The most requested scheme is the autobalancing composite cutter bar (9ABC cutters). The teeth have a surgical grade stainless steel bar positioned in the lower buccal cusps working like a knife on a cutting board against the upper plane composite surface. Over 15,000 sets of dentures have been constructed using these teeth (implant related or not).

Advantages of predetermining the prosthetics are to obtain a psychological profile of the patient. Determination of the patients' esthetic requirements
must be discussed. To determine sufficient interocclusal space, the construction of a custom bone impression tray must be taken, which also helps to establish an accurate bone impression and bite.

**Waxing and casting procedure**

The oldest but still most popular laboratory technique used for the support of the impression is to reinforce the impression with a 50% plaster and pumice mix. Apply a separating medium to the plaster and pumice, box it with ash metal, and pour with vacuum-mixed, high-quality die stone. It is important that the laboratory casting the TSI understands that it is a class two orthopedic device and should not be treated as a partial denture. Although “custom-made” larger flasks and modification of the casting rings and machine may be necessary to accommodate the size of today’s subperiosteal castings, it is essential that a closed material system be used. The mixing of materials and techniques that is commonly done in fabricating partial removable dentures in laboratories to save time and money should never be done when casting implants.

After a refractory model (waxing model) is made, it must be mounted via the bone bite. The laboratory must know the correct angle of the mandible and the proper post positions prior to waxing the case. Smooth-flowing sprues and correct use of reservoirs are critical to create a favorable flow of the metal and proper expansion and cooling down when using the oversized rings that are necessary to produce a subperiosteal casting.

Many factors go into a proper casting technique, and the manufacturing directions must never be taken too lightly. Use only virgin ingots that are FDA approved (F-75 alloy). Use a new crucible for every casting, and never reuse the button or sprues. Do not torch cast. Use induction casting equipment with a pyrometer to ensure that the proper melt temperatures are achieved. Equipment must be calibrated, inspected, and documented. Back-up equipment must be kept on line, including burn out ovens and casting equipment. Specifications for casting subperiosteal implants are printed in annual American Society for Testing Materials (ASTM) publications. Laboratories should be members of ASTM and should not determine their own procedures and techniques.

Radiographs alone will not prove a sound casting. Castings can only be proven by destructive testing, and it is suggested that, above and beyond a routine stereo microscope inspection, an ongoing quality assurance and quality control testing be conducted through a metallurgical firm to ensure optimum results.

**Passivation and sterilization**

Passivation is an oxide layer set up on the surface of the alloy by a series of sandblasting and acid bath and neutralizing agents. Passivation procedures are published in the ASTM and should be strictly followed. The dentist should not accept a nonpassivated implant.

**Fabrication of the prosthesis**

Mandibular tripodal subperiosteal implants are one of the most predictable long-term implant modalities used today.

The most commonly used procedure for obtaining the direct bone impression and retaining the patient’s original vertical dimension, centric occlusion, and same cosmetics is fabrication of the maxillary and mandibular dentures prior to surgery.

The most popular denture teeth are autobalancing composite cutter bar teeth (ABC). Often, a metal base maxillary denture is used. Prefabricating the implant prosthesis also allows time to develop a psychological profile of the patient. Two custom implant trays are also made from the tissue impression in case they might be needed.

**Stage Two Surgery**

Preoperative inspection should be accomplished at the time of the second surgery, which is usually 21 days after phase one surgery. If the tissues are still not closed completely with a good healing and tissue tonus, then the surgery for implant insertion should be delayed another week or two.

The tissues should be thoroughly examined to make sure that healed incision lines were properly positioned from stage one surgery. If not, a new incision should be made to facilitate easier insertion of the TSI.

**Insertion of the implant**

Three interrupted incisions are usually made along the original incision sites used for stage one surgery, one in the symphyseal region and two others in the ramus areas. After the incisions are made in all three areas, the tissues are gently reflected without tearing or pulling them until an adequate amount of bone is exposed, so that after the implant is inserted, the tissues can easily be pulled over the implant framework for primary intention healing.

Since the rami are much wider than the space between both posterior bodies of the mandible, it would be impossible to insert the implant “head on.” Therefore, the author first stretches the left corner of the patient’s mouth while the left posterior ramus portion of the implant is slipped over and above its final seating place in the left ramus. The right corner of the mouth and cheek on the right side is then stretched, and the right posterior portion of the implant is seated over and above its final seating place in the right ramus. In this manner, it becomes easier to seat the symphyseal portion of the implant, by allowing its lingual undercuts to extend over the anterior symphyseal crest of bone; then, by a downward thrust by the operator, both lingual undercuts of the implant will lock into the digastic undercuts while both posterior rami portions slip downward, firmly locking over their fr-
nal resting position. In this manner, an immediate three-dimensional lock of the implant is accomplished (Figs 39–43).

**Trial fitting of the prosthesis**

The implant denture should be implant borne only, the occlusion exact, and the vertical dimension of the patient restored. If any of these factors are not perfect, they can be corrected at the chair at the same visit. If too many errors in the old denture exist, the prefabricated acrylic baseplate with internal O-rings or internal clips and wax bite rim is used for the construction of a new implant denture.

**Soft tissue management and closure**

Soft tissues must always be adequately reflected off the bone, so that at the time of closure, they do not get stretched and remain passive. If excessive stretching is required to approximate the edges, the primary soft tissue incision may have to be extended or undermined at this point. If this is not successful, then a meticulous split thickness dissection of the soft tissue may be needed to separate the periosteum from the overlaying mucosal tissue. This will release the tension created by the periosteal membrane and allow a more passive soft tissue closure without damaging the periosteum. When this technique is used, the suturing is done in two layers: a deeper layer using a 2.0 Vicryl to bring together the periosteal edges as precisely as possible and a more superficial layer to ensure the passive overall closure.

When placing the periodontal dressing, care must be taken to mold it meticulously around the posterior emergencies of the implant where the loose sutured retromolar fatty tissue is brought into intimate contact with the osseous structures behind. In such a case, the correct sequence will be to suture the soft tissues passively, then place the prosthesis without impinging on the soft tissues, and finally mold the dressing around the emergencies and stabilize it with the prosthesis for two weeks.

Care must be taken to eliminate all possible soft tissue irritation or impingement by the permanent or provisional denture over the implant. If an immediate postoperative delivery of the final prosthesis is planned, the risk of tissue irritation may be minimal if the precise thickness of the soft tissue at various points is previously furnished to the lab technician, who will then manufacture the prosthesis to fit the new contours. Any adjustment will be negligible and easily carried out on the spot.

**Final seating and occlusal adjustment of implant-supported prosthesis**

After completing the surgical phase of the implant insertion, the overdenture prosthesis is seated on the mesostructure. The occlusion is checked and balanced to eliminate unilateral and intrusive interferences. The linear occlusal scheme is adjusted so that the buccal cusps of the mandibular posterior teeth occlude with the flat occlusal surfaces of the maxillary teeth. Mandibular lingual cusps contacts should be relieved. The denture base periphery is checked to make sure no impingement of the soft tissues exists (Figs 44, 45). When O-ring fixation is utilized, the posterior O-rings may be removed for the first three to four weeks postoperatively. This will prevent any lifting forces during the early stages of healing when the prosthesis is removed daily for hygiene procedures. A panoramic radiograph should be taken with the prosthesis in place to verify the final seating of the implant (Fig 46). Traction bandages may be placed across the symphysis to immobilize the muscles and help ensure proper orientation of the mentalis muscle on its attachment. This will help prevent ptosis of the chin from the mentalis reattaching inferior to its normal attachment on the symphysis menti. The patient should be advised to minimize speaking and movement of the mouth for the first postoperative week.

**Management of Incidents and Complications**

At the time of surgery, bleeding from the lingual artery may occur rarely. This will cause swelling in the floor of the mouth. Bleeding can occur as well from a branch of the facial artery. Because of a poorly placed incision, there might be difficulty in suturing the tissues together without having to introduce numerous horizontal-releasing incisions.

Immediate-term pain or bleeding can be from pressure of the existing denture on the soft tissues if the patient insists on wearing it.

Rapid postoperative swelling should be addressed with anti-inflammatory, antibiotics, etc.

In case of severe bleeding, Cutrol (purified salts of basic ferric sulfate with epinephrine) should be used topically for immediate hemostasis. If any postoperative paresthesia is reported, the appropriate treatment will be proportional to the extent and cause of the nerve injury. In subperiosteal implant surgery, irreversible nerve damage is very rare.

Exceptional paresthesias are in relation to compressive subperiosteal hematomas or overstretching of the soft tissue around the mental foramen. In both cases, combined administration of corticosteroids and vitamin B complex will be adequate to eliminate the unpleasant sensation.

**Long-term incidents**

Long-term incidents are in relation with strut exposure essentially at the posterior aspects of the implant without major handicap for the patients as long as adequate hygiene is maintained.

**CT Scan Technology**

Cemax 2000 developed at Palo Alto, Calif, allows three-dimensional imaging of a CT scan. They are interpreted by this instrumentation, which makes a hollow negative model of the anatomic portion and thus reproduces a precise replica of
the mandible or maxilla. This will avoid one surgical procedure. Some facts and factors must be considered. (1) CT scanning produces four slices per millimeter. The more slices, the more accurate the result. (2) Cooperation of the patient is required. Claustrophobia requires sedation. (3) CT scanning depends on immobility of the intramaxillary relationship. Therefore, a “bite jig” must be used in perfect occlusion and must be made precisely. It must have two characteristics: (1) an anterior perforation for tongue thrust, breathing, and salivary drainage, and (2) a tube for suction of saliva. (4) Calibration bars made of different lengths of radio-opaque material are to be fixed on the side of patient’s face with clear tape and must be made parallel to the occlusal plane. The angle of the CT scan is vertical to the occlusal plane.

**DISCUSSION**

Of the 317 TSI cases in this study, 70.34% had a variation of a full maxillary denture as the opposing dentition, either natural or implant supported. The traditional view by most clinicians performing TSIs has been that long-term survival of the implant was enhanced if the opposing dentition was a full natural denture as opposed to a rigid implant. In this study, this supposition may be relative to the shorter life span of males compared to females (Fig 48).

Follow-up care was provided and tracked for the 271 recipients. Although 24 of the patients were unavailable for follow-up, at least 110 of the patients were seen between one and two years after surgery, and a majority of 183 were seen within the first year (Fig 49).

Of the four total revision cases, three implants were removed and successfully retreated with a redesigned TSI. These failures were in some of the earliest cases, with one occurring after six months and two after approximately two years. The failures were attributed to an incompatibility with horizontal posterior mandibular flexure from a too rigid casting. The fourth total failure requiring removal was successful for nine years, but failed from chronic soft tissue degeneration and infection subsequent to radiation treatment for throat cancer. This case was not re-treatable. Three of the four partial revision cases required removal and replacement of one of the posterior segments of the implant with a redesigned segment. These failures were attributed to errors in design, resulting in bone resorption and settling of the posterior load-bearing struts due to unequal occlusal load distribution concentrating these forces directly under the primary posterior strut. The fourth case required removal of both posterior segments and is still in function, with the anterior segment securing a posterior tissue-borne overdenture. Two patients experienced permanent paresthesia unilaterally. Both of these patients were those who underwent partial revision treatment. Five patients experienced transient paresthesia, which dissipated in one to three months. All five of these cases underwent full reflection of the mental nerve. No paresthesia was experienced in those cases where the mental nerve was not surgically exposed. Secondary strut dehiscence was treated by surgical exposure and removal of the secondary strut. Infections occurred postoperatively in 12 cases during primary healing following second stage surgery. The remaining 10 incidents were due to foreign bodies and/or inadequate hygiene. All were treated with appropriate antibiotic therapy and improved hygiene (Fig 50).

All of the revision cases occurred within the group of implants that were placed in the January 1984 to December 1987 group. As noted above, these were basically due to design errors and can be considered part of the “learning curve.” The decline in the number of implants placed in more recent periods roughly parallels the increase in the number of alternative treatments available and the dramatic increase in the number of clinicians performing these alternatives treatments (Fig 51).

Success of the TSI can be attributed to the distribution of occlusal forces to those areas of the mandible that have dense cortical bone, specifically, the symphysis between the mental foramina and the ramus, including the retromolar fossa and triangle, anterior aspect of the ramus, external oblique ridge, and buccal aspect of the ramus.

Load-bearing posts distribute masticatory forces along vectors that coincide in harmony with the natural-occurring stress trajectory—the dental trajectory. This trajectory leads forces away from the dental arch to dissipate throughout the ramus to the coronoid and condylar processes. The retromolar area cortical bone thickness studies by Smith et al fit in with these factors to reinforce this overall design hypothesis. The TSI, by virtue of its specific design for each individual patient, aids...
FIGURE 47. Opposing maxillary dentition.
FIGURE 48. Age and gender distribution.
FIGURE 49. Follow-up.
FIGURE 50. Complications.
FIGURE 51. Longevity distribution for successful cases.
in directing a substantial portion of occlusal force directly to the retromolar area through the ridged mesostructure.

The TSI braces the weakest portion of a severely atrophied mandible, bypasses dehiscent inferior alveolar nerves and mental neurovascular bundles, and distributes occlusal forces throughout its mesostructure. The body of the mandible between the ramus and mental foramen is substantially relieved of the potentially traumatic occlusal loads experienced by endosseous interforaminal cantilevered implant systems. As a bonus, the patient is placed into function with a full complement of posterior teeth within 24 hours or three to four weeks, restoring centric relationship and vertical dimension of the face.

The two surgical phases of treatment involved in fabricating and inserting a TSI are completed either 12-24 hours after the first surgery or three to four weeks following the primary surgery. The patient is provided a stable dental prosthesis immediately or soon after the second surgery. With osseointegrated root form implants, a healing period of four to nine months has become customary to allow for osseointegration prior to initiation of the prosthetic phase of treatment. In treating severely atrophied mandibles using osseo-integrated root-form implants, extensive bone grafting procedures are required months prior to placing the implants. Such cases can take well over a year before the prosthesis can be fabricated, and the patient is without a lower prosthesis during much of the treatment. Additionally, multiple surgeries with a team of doctors from different surgical disciplines require multiple hospital stays, and morbidity of the osseous donor sites often occurs. With today's escalating health care costs, especially in the US, the surgical expense of restoring patients with extreme atrophy of the mandible, who are often elderly, and the delay in providing them a stable prosthesis must be seriously considered.

Patients between 70–90 years of age shouldn't be subjected to extensive and multiple surgeries unless absolutely necessary, because such multiple surgeries force them to be edentulous during the prolonged healing periods required. A stable dental prosthesis is the primary objective. Therefore, from the standpoint of longevity, load-bearing capabilities, functional efficiency, ease of prosthetic maintenance, and absence of serious sequelae in the event of failure, the TSI should always be considered.

**Conclusions**

The TSI designed for restoring the severely atrophic mandible must be performed on an individual basis as a custom-designed and -fabricated device. Weekend courses featuring this implant are not as readily available as are those on commercially produced root-form implants. However, in-depth training in these implant techniques has been incorporated in several comprehensive postgraduate implant programs at numerous universities.

Due to the high rate of success the authors have experienced utilizing TSIs for the treatment of severe and extreme atrophy of the mandible, TSI procedures should be incorporated in every postgraduate implant teaching program. The TSI as begun by Linkow and pioneered by himself, Wagner, and Chanavaz does indeed change "dental cripples" into well-functioning members of society in a minimal time and at a modest expense.

**References**


