“DIAGNOSIS&TREATMENT PLANNINGIN DENTAL IMPLANTS

RAJASTHAN UNIVERSITY OF HEALTH SCIENCES, JAIPUR

Library Dissertation submitted to

the Rajasthan University of Health

Sciences, Jaipur,in partial fulfillment

of the requirements for the degree of

MASTER OF DENTAL SURGERY

In

DEPARTMENT OF PROSTHODONTICS AND CROWN

&BRIDGE AND IMPLANTOLOGY

DASWANI DENTAL COLLEGE & RESEARCH CENTRE, KOTA

By

DR. SHASHANK VINAYAK KALDATE

POST GRADUATE

STUDENT

UNDER THE GUIDANCE

OF Dr.Ashish Pandey

Professor And Head of Department

DEPARTMENT OF PROSTHODONTICS AND CROWN &

BRIDGE AND IMPLANTOLOGY

DASWANI DENTAL COLLEGE & RESEARCH

CENTREKOTA, RAJASTHAN

2021-2024

16: 80 – 89.

1. 320.

CONTENTS

Table of Contents

Introduction

In 1969, Brånemark et al published landmark research documenting the successful osseointegration of endos seous t itanium implants. Since then these methods for the surgical placement of dental implants have had a profound influence on the pr actice of dentistry. Implants have become the treatment of choice in many, if not most, situations when missing teeth require replacement. Studies of the interaction between implant- supported restorations and the surrounding oral environment appear, fortuitously, to support the conclusion that the human host response to oral implants is favourable.

However, implants are not without potential problems. A tangible number of implants may not integrate or survive for long-term function. Complications and loss of implants can be costly, both in terms of time and financial resources. Loss of integration can be troublesome, resulting in an edentulous space more difficult to restore than prior to implant placement. The ability to reliably identify patients and conditions with greater potential for failure would be valuable.

With appropriate diagnosis and conscientious treatment planning, the use of endosseous oral implants enjoys good prognosis.

Review of Literature

Smith DE, Zarb GA [1] in their review article have recommended six criteria for determining the clinical success of endosseous dental implants. Of these, mean vertical bone loss of less than 0. 2 -mm after the first year of service has been proposed.

Dharmar S [2] conducted a study to determine whether the course of the mandibular canal can be more clearly visualized by tilting the patient's head approximately 5 degrees downward with reference to the Frankfort horizontal reference bar of the Orthopantomogram machine. In 91 % of the radiographs taken in this position, the mandibular foramen, mandibular canal, and mental foramen were visible. The angulation of the patient's head reduced the chances of superimposition on the contralateral sid es, making these structures clearly visible.

Garcia LT, Oesterle LJ [3] surveyed a large population to measure the incidence of natural tooth intrusion in implant - assisted fixed partial dentures (IAFPD) and to try to identify a correlation between type of implant and/or type of connector. Natural tooth intrusion occurred in 3. 5% of the patient population specifically treated with IAFPD. No correlation could be made between incidence of intrusion and the type of implant or type of connector used.

Wallace RH [4] investigated the relationship between cigarette smoking and dental implant failure. The records of 56 dental implant patients with a total of 187 endosseous dental implants placed over a four year period were evaluated. A significant association between increased implant failure rates and cigarette smoking with failure rates of 16.6% in smokers compared to 6.9% in non-smokers was observed. The anterior maxilla was the only intra - oral site found to have a significant increase in failure rates in smokers compared to non-smokers. Also, implant length was shown to be a significant factor with shorter implants (<10 -mm) being more susceptible to failure in smokers.

Becker CM, Kaiser DA [5] have detailed the indications to use a cantilever implant-supported fixed prosthesis based on gathering data from the literature.

Bergendal T, Magnusson T [6] conducted a prospective 3 - year follow up study to evaluate the signs and symptoms of temperomandibular disorders following treatment with implant - supported fixed prostheses. 78 patients referred for treatment with IFPs were evaluated for the presence of signs and symptoms of TMD before the start of treatment and after 1 and 3 years. Clinical signs of dysfunction based on the Helkimo index were reported to

have reduced numerically but not statistically significantly the anamnestic index used to evaluate subjective symptoms had decreased statistically significantly at the 3 - year follow up. Of note, improvement was statistically significant only for the variables joint sounds and pain when opening the mouth wide. All patients were satisfied with the treatment received. The results from the investigation showed that treatment with IFPs had a good and lasting effect on the functional status of the masticatory system as well as on subjective symptoms of TMD and chewing ability in the vast majority of patients treated.

Hatley CL, et al [7] investigated the effects of implant proximity on inter-implant bone height, density, and osseointegration using digital radiography and histology. A total of 80 implants were placed in 20 New Zealand White Rabbit tibias. Four 8.5-mm implants were placed in the medial aspect of the tibial crest at inter - implant distances of approximately 1, 1.5, and 3 mm. Implants were allowed to osseointegrate for 90 days after which the animals were sacrificed. The initial and postmortem digital radiographs were evaluated for inter-implant distances, vertical bone height changes over time and bone density changes over time implant pairs. A histologic evaluation of sagittal sections was performed. The actual inter-implant distances were consistent in a range of 0.2 mm. Bone height increased significantly from presurgical levels at all three

locations. The amount of bone growth at the 1 -mm separation site was significantly greater than the 1.5 -mm site and the 3 -mm site, whereas bone growth at the 1. 5 - and 3-mm sites did not show significant differences. No significant differences in bone density among the 3 inter-implant distances were observed. The authors concluded that placing implants closely together does not adversely affect bone height or density and, in fact, placing implants closer together may increase bone growth.

Dula K, et al [8] have outlined the indications for the most frequently used imaging modalities in implant dentistry based on clinical need and biologic risk for the patient. Biologic risk was evaluated based on dose measurements. They demonstrated that the risk from a periapical radiograph is 20% of that from a panoramic radiograph. A panoramic radiograph and a series of 4 conventional tomographs of a single-tooth gap in the molar region carry 5% and 13% of the risk from computed tomography of the maxilla, respectively.

Andersen E, et al [9] compared the success rate and marginal bone resorption of a narrow-diameter self-tapping implant placed in less available bone volume with the standard-diameter self-tapping implant placed in a well-dimensioned alveolar process. 55 patients were included in the study; 27 patients received 28 standard - diameter (3.75 -mm) implants, and 28 patients received 32 narrow

diameter (3. 25 -mm) implants replacing either a central or a lateral incisor in the maxilla. Follow-up examinations were performed at 6 months after loading and 1, 2, and 3 years after loading. Two narrow-diameter implants were lost after 6 months (93.8% success rate) but no other failures were subsequently observed in any of the groups after that. In both groups, marginal bone loss followed thesame pattern and was recorded radiographically to be a mean of 0.4 mm from the first to the last examination.

Khayat PG, Hallage PGH, Toledo RA [10] conducted a follow-up study on 131 wide diameter (4.7 mm) placed in 71 patients. 7 patients (14 implants) were lost to follow -up. Six implants were removed before completion of prosthetic treatment. The remaining 111 implants were evaluated at the recall examination. Almost all implants (109) supported a fixed prosthesis. The mean loading time was 17 months. No implants were lost during the loading period. The overall survival rate was 95%. The survival rate for mandibular implants was 94%; for maxillary implants, it was 96%.

Lindh T, et al [11] conducted a retrospective multicenter study on implants combined with natural teeth. The study comprised 185 implants in 111 patients. Gathering of data, which were taken from patient records, followed a strict protocol. The cumulative implant

survival was found to be 95.4% up to 3 years of follow -up. The most severe complication other than loss of osseointegration (6/18 5) or peri-implant infections (4/ 183) was intrusion of the abutment teeth, which occurred in 5% of the cases. In all instances, the intrusion was seen in constructions with nonrigid forms of connection between the implants and teeth.

Gross MD, Nissan J [12] investigated the influence of inefficient bone volume in the maxilla on stress distribution around implants under occlusal loading. Two model systems were used. First, a 2-dimensional photoelastic anatomic frontal skull sectional model was prepared in the first molar region. Left and right maxillary metal cylinder implant analogues inclined at 0 and 25 degrees to the sagittal plane were loaded in simulated intercuspa tion. Second, a dry skull lined with a photoelastic coating on the buccal aspect over an embedded cylinder implant was prepared in the first molar region. Principal stress concentration was photographed on axial and nonaxial implant loading. On simulated intercuspal loading, maximum stress concentration occurred at the buccal concavity in both the 2- dimensional anatomic photoelastic and skull models. There was no stress concentration at the apices of the maxillary implants in the 2 -dimensional model. On lateral loading of the skull model, stress was distributed along the entire buccal aspect of bone adjacent to the implant, with a higher concentration at the buccal concavity.

The authors concluded that implant diameter and placement should be given consideration to preserve adequate facial bone thickness for better treatment outcomes.

Friberg B, Ekestubbe A, Sennerby L [13] evaluated the outcome of 3 different implant diameters, with special focus on the 5 .0 -mm diameter implant. 98 patients with a mean age of 62 years were included in this retrospective study. The mean follow-up period was 2 years and 8 months. A total of 379 implants (3.75 mm diameter, n = 146; 4. 0 mm diameter, n = 76; 5.0 mm diameter, n = 157) were placed in 29 edentulous and 70 partially edentulous jaws. Failure rates of 5. 5%, 3. 9% and 4.5% was reported in the 3.75, 4. 0 and 5. 0 diameter implants respectively. All failures were recorded in maxillae. The authors recommended the use of an adapted bone site preparation technique (2. 7 to 2. 85 mm final twist drill for 3. 75 mm diameter implants and 3.0 mm twist drill for 4. 0 and 5. 0 di ameter implants) and extended healing periods (8 to 10 months) for achievement of the best primary and secondary implant stability possible.

Kumar A, Jaffin RA, Berman C Kumar, Jaffin [14] evaluated the effect of smoking on achieving initial osseointegrat ion whensurface-modified (SLA) dental implants were used. 1,183 implants were placed in 461 patients over a period of 18 months. The group

of smokers consisted of patients who smoked a half pack or more of cigarettes per day. The overall success rate for smokers and non-smokers in achieving osseointegration was 98.1%. A success rate of 97% in smokers was reported as compared to 98.4% in non-smokers.

Sugerman PB, Barber MT [15] reviewed the literature on the effect of systemic and local pathology on the success rate of dental implants. The authors have outlined a systematic approach to dental implant patient selection and have recommended centralized reporting of dental implant outcomes.

Tangerud T, Gronningsaeter AG, Taylor A [16] evaluated fixed partial dentures supported by a combination of natural teeth and implants in a variety of clinical situations. In 30 patients, 86 teeth and 85 implants were used as supports for 30 FPDs of varying extension (mean = 8.6 units); 23 in the maxilla and 7 in the mandible. A removable rigid connector design was used. Five implants were lost prior to the placement of prostheses, 2 were lost after loading, giving survival rates of 91. 0% in the maxilla and 95.5% in the mandible. Changes in plaque accumulated, bleeding on pro bing, pocket depths, and marginal bone level were acceptable. These findings, together with the patient satisfaction experienced, indicated that the combined support of implants and teeth for fixed prostheses may be appropriate treatment for patients.

Wang T, et al [17] investigated the effects of prosthesis materials and prosthesis splinting on the peri-implant bone stress under static loads. A 3-dimensional finite element model consisting of a bone block and 2 simulated premolar crowns supported by 2 adjacent cylindrical implants without immediately surrounding cortical bone was generated for the study. and used to The peri -implant maximum equivalent bone stress was evaluated when a vertical or a horizontal load of 1N was applied to the center of a single resin, gold alloy, or porcelain crown, nonsplinted or splinted to the adjacent crown. The numeric results indicated that: (1) in a single crown, no significant difference could b e found in the maximum V M stress between different materials for both vertical and horizontal loading; (2) splinting the crowns reduced the maximum V M stress induced b y the horizontal load, and the maximum V M stress increased about 1 4 % for the horizontal loading when the restorative material was changed from gold alloy or porcelai n to resin. Under the condition of this study's analysis, prosthesis materials of a single crown have insignificant effects on the peri-implant bone stress. The authors recommended splinting the crowns of adjacent implants with rela - tively stiff restorative materials for implants surrounded by poor - quality bone.

Davis DM, Packer ME, Watson RM [18] conducted a 5 - year follow-up study to compare the maintenance requirements of implant - supported fixed prostheses with cantilever arms in completely edentulous jaws when opposed by fixed prostheses of similar design, by natural teeth, or by complete dentures. The dental records of 37 people were examined. 6 were provided with fixed prostheses in both arches, 22 with a fixed prosthesis in the mandible opposed by a complete denture, and 9 with a fixed prosthesis opposed by natural teeth. The denture teeth and acrylic resin were repaired on 44 occasions in the group with implants in both jaws, on 14 occasions in the group with implants opposed by natural teeth, and twice in the group in which the implants were opposed by a complete denture. The group with implants in both jaws was more likely to fracture the gold-alloy framework, which occurred on 6 occasions. The group with implants in both jaws was significantly different from the other two groups in relation to higher incidence of fracture of the teeth and gold-alloy framework.

Tosun T, Karabuda C, Cuhdarolu C [19] used polysomnographic analysis to confirm sleep bruxism (SB) and to evaluate clinical findings of dental implant treatment in SB patients. A retrospective analysis of 368 patients with a total of 838 endosseous implants was conducted. 19 patients who experienced mechanical complications, such as implant or abutment fractures, loosened gold screws, or

occlusal surface wear or damage, were selected for polysomnographic analysis to monitor sleep symptoms. 6 patients in the study group were identified as having SB, and this was confirmed by polysomnographic analysis. Polysomnographic study was evaluated as an effective, low- cost method to confirm occlusal parafunctional habits during sleep.

Morneburg TR, Proschel PA [20] investigated whether systematic modifications of occlusal features or food consistency are suitable to reduce the loading of implants. Ten patients each of whom had a gap in the chewing center (second premolar or first molar) were provided with a fixed prosthesis supported by two implants. Strain gauges attached to the abutments recorded forces in three dimensions. In each person, the original FPD was successively replaced by three FPDs with different occlusal schemes: The first had steep cusps, the second had flat cusps, and the third had the same cuspal inclination as the first but a narrow occlusal surface. Subjects chewed gummy bears and bread as a tough and a soft bolus, respectively. In chewing of gummy bears, the mean vertical forces of the three FPDs ranged between 264 and 284 N and were not significantly different. The mean bending moments amounted to 27 Ncm and 24 Ncm with steep and flat o cclusal slopes, respectively. With the narrow occlusal surface, the bending moments were reduced by 48%, to a mean of 11 Ncm. Chewing of

bread yielded similar relations with lower mean vertical forces and bending moments. Narrowing the orovestibular width of the occlusal surface by 30% caused a significant reduction of lateral force components. The authors recommended a reduced orovestibular width of the occlusal surface in unfavorable loading conditions and the chewing of soft food during the healing perio d in cases of immediate loading.

Tada S, et al [21] conducted a 3 - dimensional finite element analysis to evaluate the influence of implant type and length, as well as that of bone quality, on the stress/strain in bone and implant. Two types (screw and cyli nder) and 4 lengths (9.2, 10.8, 12.4, and 14.0 mm) of titanium implants were buried in 4 types of bone modeled by varying the elastic modulus for cancellous bone. Axial and buccolingual forces were applied at the center of the abutment. Regardless of load direction, maximum equivalent stress/ strain in bone increased with a decrease in cancellous bone density. Under axial load, especially in the low- density bone models, maximum equivalent strain in cancellous bone was lower with the screw -type implant than with the cylinder-type implant. It was also lower with the longer implants than with the shorter implants. Under buc - colingual load, equivalent stress/strain was influenced mainly by bone density. The results of this study suggest that cancellous bone of higher rather than lower density might ensure a better

biomechanical environment for implants. Moreover, longer screw - type implants could be a better choice in a jaw with cancellous bone of low density.

Bryant SR, Zarb GA [22] evaluated the crestal bone loss proximal to dental implants in older and younger adults. Two groups of 35 complete dental implant prosthesis sites were selected by matching sites in 32 older adults with 166 implants to sites in 34 younger adults on the basis of possible confounding f actors including gender, prosthetic design, implant number, arch, year of surgery, and opposing dentition. Statistical comparisons were made of mean crestal bone level at loading and mean annual crestal bone loss during the first year, first to fourth year , after first year, and after fourth year of loading with periapical radiographic measurements. No significant differences were found between the groups. The study suggests that crestal bone loss around oral implants does not differ with age.

Tawil G, Younan R [23] evaluated the clinical outcome of shorter length, machined- surface implants when used exclusively in the treatment of various forms of edentulism. 269 screw-type implants, 10 mm or shorter, were placed in 111 consecutively treated patients. Of the total, 88.8% were placed in the mandible and 11.2% were placed in the maxilla; 95.2% were used to treat partially edentulous

situations, including single-tooth losses, of which 96.6% were in the premolar and molar regions. The patients were followed for periods of 12 to 92 months. Of the 269 placed implants, 12 were lost. The overall survival rate was 95.5%. Bone quality 2 and 3 (Lekholm - Zarb classification) was found in 88.8% of the treated sites. There was no statistical difference in the survival rat e of the 10 -mm implants when compared to the shorter series or between the various implant diameters. This study supported the survival of short, machined-surface implants when used for the treatment of partial edentulism in bone of good quality. Bone quality appeared to be the critical factor in implant survival, rather than bone quantity, in this patient series.

Prosper L, et al [24] conducted a randomized study to evaluate and compare the long-term success rates of wide diameter (5. 9 mm) implants that were placed in fresh extraction sockets in association with resorbable bone substitutes or a resorbable membrane. 83 partially edentulous adult patients, in whom 1 or more implants had been placed into fresh posterior mandibular or maxillary sockets, were included in the study. A total of 111 implants were placed, 36 in mandibles and 75 in maxillae. 56 implants were placed in combination with resorbable hydroxyapatite (HA group) and 55 with a resorbable membrane (MR group). Intraoral radiographs and follow-up examinations, including verification of implant stability

via the Periotest, were carried out at second- stage surgery 3, 6, 9, and 12 months later; and then annually up to 4 years after placement of the definitive restoration. Two implants failed in the MR group, one at 3 months and one at 9 months after placement; 1 implant failed in the HA group at 4 months after place ment. After 4 years, the implant success rate was 97.3%. The success rate did not differ significantly between the HA group (98.2%) a nd the MR group (96.4%). The authors concluded that implants placed in combination with a resorbable allogeneic material or with a resorbable membrane provided predictable long-term results when restored with a fixed partial denture.

Kreisler M, et al [25] conducted a retrospective study to investigate alveolar bone resorption in the edentulous maxilla in patients with implant-supported mandibular overdentures. 35 healthy, completely edentulous patients (mean age of 59.7 years) were included. They had received two implants between the mental foramina. New bar - retained mandibular overdentures and maxillary complete dentures were fabricated. Standardized panoramic radiographs taken subsequent to loading and at annual recall visits for up to 8 years were measured for alveolar bone loss in the maxilla. Differences in the resorption rate between the anterior and posterior parts of the maxilla were investigated using a planimetry program . The results showed that residual ridge resorption was significantly more

pronounced in the anterior (5 to 11%) than posterior maxilla (2% to 7%) from the second through eighth years.

Lin C, Wang J [26] analyzed the biomechanics in an implant/ tooth - supported system under different occlusal forces with rigid and nonrigid connectors by adopting a nonlinear finite element (FE) approach. A model containing 1 implant placed in the second molar position splinted to the mandibular second premolar was constructed. Stress distributions in the splinting system with rigid and nonrigid connectors were observed when vertical forces were applied to the tooth, pontic, implant abutment, or complete prosthesis in 10 simulated models. The displacement obtained from the natural tooth increased 11 times than that of the implant, and the peak stress values within the implant system increased significantly when vertical forces acted only on the premolar of a fixed prosthesis with a rigid connector. The peak stress values seen in the splinting prosthesis were not significantly different when vertical forces (50 N) were applied to the pontic, molar (implant) only, or the entire prosthesis, respectively, regardless of whether rigid or nonrigid connectors were used. Moreover, the peak stress values in the implant system and prosthesis were significantly reduced in single- or multiple- contact situations once vertical forces on the pontic were decreased. The nonrigid connector (keyway device) significantly exploited its function only when the splinting

system received light occlusal forces. Minimization of the oc clusal loading force on the pontic area through occlusal adjustment procedures to redistribute stress within the implant system in the maximum intercuspation position for an implant/tooth -supported prosthesis was recommended.

Brosky ME, et al [27] measured the anterior cantilever of mandibular implant-supported fixed prostheses, and the proportions of anterior to posterior cantilever lengths relative to the anteroposterior spread. 13 edentulous patients were included in the study. Each patient had 1 mandibular impression made with irreversible hydrocolloid, which was poured in type III gypsum. A precision 3D measuring stylus was used to measure the anteroposterior spread, and anterior and posterior cantilevers. Presence or absence of screw loosening was noted. The mandibular anterior cantilever lengths ranged from 5.5 to 14.4 mm (mean 8.78 mm). Posterior cantilever lengths ranged from 9.2 to 20.9 mm (mean 16.2 mm). Anteroposterior spread ranged from 5.2 to 12. 3 mm (mean 7. 9 mm). From a total of 65 retaining screws, 7 were found to be completely loose. No apparent correlation was found between length of mandibular anterior cantilever and screw loosening, although the ratio of posterior cantilever to anteroposterior spread (2: 4) was signifi cantly associated with screw loosening.

Geramy A, Morgano SM Geramy and Morgano [28] conducted a finite element analysis of a single mandibular molar crown supported by: (1) a standard 3.75 -mm- diameter implant, (2) a 5 - mm, wide- diameter implant, and (3) double standard -diameter implants, and to compare the induced displacements as a result of various loading conditions. Each model was analyzed with 2 force magnitudes (35 N and 70 N) and with 2 force directions (vertical and 15 degrees to the vertical axis). Displacements were evaluated along 3 primary axes, mesiodistal, faciolingual, and superior-inferior. The results of the study showed that mesiodistal and buccolingual displacements for the crown supported by the 5-mm-diameter implant were reduced by approximately 50% compared with the crown supported by the3.75-mm implant when the crowns were loaded at the distobuccal cusp tip or the distal marginal ridge. The double- implant design recorded the least mesiodistal displacement with off- center loading of the crown. The authors concluded that wider diameter or 2 implants may be considered for the replacement of a missing single mandibular molar.

Hekimoglu C, Anil N, Cehreli MC [29] compared strains induced around a natural tooth opposing an implant with strains around occluding implants under static and dynamic loads. Occlusion was created between a natural molar tooth and an implant in 1 side, and

2 implants in the contralateral side of acrylic resin models of both jaws. Strain- gauges were bonded around the neck of the natural tooth and implants, and strains were measured under 75 N and 100 N static axial and lateral dynamic loads in separate load situations. The strain data of the natural tooth and implants were compared for each load. Under static and dynamic loads, strain magn itudes around a natural tooth were significantly lower than that of an opposing implant and occluding implants in me contralateral side. There was a general tendency for increased strains around the implant opposing natural tooth under higher loads and par ticularly under lateral dynamic loading.

Himmlova L, et al [30] conducted a 3 - dimensional finite element analysis study to determine which length and diameter of implants would be best to dissipate stress. The models simulated implants placed in vertical positions in the molar region of the mandible. A model simulating an implant with a diameter of 3. 6 mm and lengths of 8 mm, 10 mm, 12 mm, 14 mm, 16 mm, 17 mm, and 18 mm was developed to investigate the influence of the length factor. The influence of different diameters was modeled using implants with a length of 12 mm and diameters of 2.9 mm, 3. 6 mm, 4.2 mm, 5. 0 mm, 5.5 mm, 6.0 mm, and 6. 5 mm. The masticatory load was simulated using an average masticatory force in a natural direction, oblique to the occlusal plane. Maximum stress areas were located around the

implant neck. The decrease in stress was the greatest (31.5%) for implants with a diameter ranging from of 3.6 mm to 4. 2 mm. Further stress reduction for the 5.0 -mm implant was only 16.4%. An increase in the implant length also led to a decrease in the maximum von Mises equivalent stress values; the influence of implant length, however, was not as pronounced as that of implant diameter.

Penarrocha M, et al [31] investigated the amount of crestal bone loss during the first year after implant placement and its relationship to smoking, implant location, and morphology. In addition, panoramic, conventional periapical, and digital radiographs were evaluated for accuracy in assessment of peri- implant bone loss. A total of 108 implants (59 in the maxilla and 49 in the mandible) were placed in 42 patients (16 men and 26 women). Of these, 94 implants were located in the posterior region versus 14 in the anterior region. 61 implants were placed in non- smokers versus 47 implants in smokers. Implant length and diameter varied according to the site selected. Crestal bone levels were measured using the three imaging modalities at loading and after 1 year. The results of the study provided an association between increased marginal bone loss and smoking as well as implant location in the maxilla. No correlation was found between implant dimensions and peri -implant bone loss. Conventional periapical and digital radiographs were found to be more accurate than panoramic radiographs.

Vigolo P, et al [32] conducted a 7 - year retrospective study based on dental records from 192 small-diameter implants (2.9 or 3 .25 mm) placed in 165 patients from 1992 to 1996. 94 implants supported single-tooth cemented restorations while the remaining 98 implants supported cemented or screw- retained partial prostheses. The total implant survival rate was 95.3%. Four implants were lost at second - stage surgery, and 5 more were lost after loading. The results suggest that small-diameter implants can be successfully included in implant treatment. They may be preferable in cases where space is limited.

Zinsli B, et al [33] evaluated the survival rate of 298 smaller diameter implants (3 .3 mm) placed in 149 partially or completely edentulous patients over a 10-year period using a 2-stage protocol. The implants were restored with fixed restorations with a fixed full-arch or removable overdenture being the predominant type. The cumulative 5 - year survival rate of the implants was 98. 7% (96.6% after 6 years). Prosthetic complications were mostly limited to loose occlusal screws and sore spots caused by the denture base.

Mordenfeld MH, et al [34] conducted a retrospective clinical study of 78 wide- diameter (5 .0 mm) implants used in posterior edentulous areas. 52 patients were included in the study (34 women and 18 men – mean age 55 years). 23 implants were placed in the maxilla and 55

in the mandible. The mean time in situ was 33 months (range of 11 to 58 months). A total of 8 implants were lost by the t ime of reexamination – 5 in the maxilla with a failure rate of 23% versus 3 in the mandible with a failure rate of 5%. An overall success rate of 89.8% was reported.

Kronsterom M, Trulsson N, Soderfeldt B [35] compared treatment outcomes among subjects with complete arch fixed prostheses in the maxilla, supported by implants or a combination of natural teeth and dental implants. 21 patients with maxillary tooth- and implant-supported fixed prostheses and 21 patients with maxillary implant - supported fixed prostheses were included in the study. All prostheses had a minimum of 8 units, at least 4 of which were in one quadrant. Subjects in both groups were mailed a questionnaire consisting of 15 questions focused on various factors related to treatment outcome, such as oral function and patient satisfaction. The response rate was 86%. Both groups reported a high satisfaction rate for most items. Most individuals in both groups reported great improvement in chewing ability and few reported phonetic disturbances. No statistically significant differences were found between the groups.

Worthington P [36] has described the concerns over injury to the inferior alveolar nerve during implant placement and has proposed a formula to aid in the radiographic assessment based on which a suitable implant length can be selected.

Neves FD, Mendonca G, Fernandes AJ [37] have described a procedure to analyze the influence of lip line and lip support on the esthetics of an existing maxillary complete denture, revealing potential limitations when planning a fixed implant-supported prosthesis.

Goene R, et al [38] conducted a retrospective, multicenter study to compare implant performance based on length. A total of 188 patients received 311 short, textured (TPS) implants that were placed mostly in soft bone and supported 216 partially edentulous cases in the maxilla or mandible. Most restorations (95.2%) were short- span fixed restorations placed in the posterior sextants. During 3 years of follow-up, a cumulative success rate of 95.8% was reported. The authors concluded that the overall success rate of the shorter length, textured implants compared favorably with available literature for the performance of implants in general, and short implants in particular.

Cordaro L, et al [39] reported on the implant success rate, prosthetic complications, and the occurrence of tooth intrusion, when complete-arch fixed prostheses, supported by a combination of implants and teeth, were fabricated for patients with normal and reduced periodontal support. 19 patients were treated with combined tooth- and implant- supported complete-arch fixed prostheses and were retrospectively evaluated after a period varying from 24 to 94 months. 9 patients showed reduced periodontal support (RPS group), and 10 patients had nor mal periodontal support of the abutment teeth ([NPS group]). 90 implants and 72 tooth abutments were used to support 19 fixed partial dentures. Screw- and cement- retained metal-ceramic and metal-resin prostheses were fabricated with rigid and nonrigid connectors. Implant survival and success rates, occurrence of caries and tooth intrusion, and prosthetic complications were recorded. One of the 90 implants was lost (99% survival rate) while 3 implants showed more than 2 mm of crestal bone loss (96% success rate). No caries were detected, but 5.6% (4/72) of the abutment teeth exhibited intrusion. No intrusion of teeth was noted in the patients exhibiting reduced periodontal support regardless of the type of connector or when a rigid connector was used for either group. The number of intruded teeth was significantly greater in patients with intact periodontal support and was associated with a non-rigid connector.

Treatment Planning: A Sequential Analysis

Over the last decade, reconstruction with dental implants has changed considerably. Rather than merely focusing on the tooth or teeth to be replaced, today's implant practitioner considers a broad and complex set of inter-woven factors before formulating a treatment plan. The treatment planning phase is divided into three stages:

1) Initial consultation
2) Joint treatment planning
3) Final treatment considerations

1) Initial Consultation

The initial consultation is the first step in determining whether a patient qualifies for a reconstructive procedure. If implant therapy is an appropriate option a preliminary treatment plan may be developed. The main considerations are:

- Chief complaint of the patient
- History of the present illness
- Medical history
- Clinical examination and Radiographic assessment

Chief Complaint of the Patient

The focus of the evaluation of the patient's chief complaints is the factors that have prompted the person to seek rehabilitation. Sometimes, the discussion may reveal additional concerns beyond the initial complaint. Any additional information can be an important diagnostic aid and should be noted. Importantly, esthetic concerns of the patient should be assessed and placed into context. Although dental implants c a n enhance esthetics, phonetics, and bite force, it is important to identify unrealistic expectations that patients regarding the treatment.

History of Present illness

The practitioner must identify what in the patient's history produced the present situation especially in cases where atrophy in the maxilla or mandible is severely advanced.

Medical History

In gathering the patient's medical history, special attention should be given to whether the patient has the ability to physi cally and emotionally sustain all the procedures that may be required in implant therapy, including surgery, a variety of anesthetics and pain-control drugs, and prosthetic rehabilitation.

In addition to obtaining the patient's health history, the doctor must assess vital signs, blood pressure, pulse, and

respiration and record these assessments in the patient's chart. When a patient has not had a comprehensive medical check -up for several years or when findings are positive on the health questionnaire, additional laboratory testing may be advisable.

Combining the information from the health questionnaire, the vital signs, and the laboratory test results will enable the doctor to categorize each patient into one of the classifications of pre - surgical risk, as formulated by the American Society of Anesthesiology (ASA) (Table 1).[15]

Most patients who seek implant reconstruction fall into the class I and II categories and some times class III. For obvious reasons, patients in classes IV, V and VI are not a ppropriate candidates for implant procedures.

Information obtained from this categorization will enable the implant practitioner to more effectively decide what kinds of procedures should be undertaken, where the surgery should be performed, and what kind of anesthesia is appropriate. Further more, in the cases of patients categorized as class III, preparatory measures may need to be undertaken, such as stabilizing or controlling a diabetic, before implant surgery can be considered.

Table 1: ASA Classification of Physical Status

P1	Normal, healthy patient
P2	Patient with mild systemic disease with no functional limitation, i. e., a patient with a significant disease that is under good day- to-day control, e. g., controlled hypertension, mild COPD (bronchi tis, emphysema), oral agents for diabetes mellitus, stable on digoxin for atrial fibrillation.
P3	Patient with severe systemic disease with definite functional limitations, e. g., a diabetic on insulin, significant COPD with low exercise tolerance, high blood pressure despite taking 2 or 3 antihypertensive medications.
P4	Patient with severe systemic disease that is a constant threat to life.
P5	Moribund patient who is not expected to survive 24 hours.
P6	Declared brain-dead patient whose organs are being removed for donor purposes.

Clinical Examination and Radiographic Assessment

In addition to questioning patients about their dental history, a through examination should be conducted. An evaluation of the hard and soft tissue of the entire maxillo-facial region is warranted to rule out any malignancy. Temperomandibular status should be evaluated.

The dental examination includes visual examination, palpation of the superficial structures, vertical dimension, occlusal planes, maxillomandibular relationships, existing occlusal scheme, span of edentulism, hard and soft tissue undercuts, adjacent natural teeth if present, opposing dentition, interarch space, lip positions, midline, and periodontal status. Diagnostic impressions should be made to obtain accurate study models. Bone-mapping procedures may be carried out to assess the available bone volume.

Based on this clinical examination, an appropriate imaging modality is selected to attain information about the proposed implant site.

The patient's facial appearance should be documented with pre- operative extra- oral and intra-oral photographs. The initial consultation should also serve to educate and orientate the patient. Visual aids (such as educational models, photographs and videos) and printed literature are useful in this regard.

2) Joint Treatment Planning

The next phase in the treatment planning process involves the entire implant team including the surgeon (if separate), prosthodontist and other specialists. The hygienist or laboratory technician may also be included. The planning conferences provide opportunities for the team to review the patient's chief complaints, expectations, history and current medical and dental status. Based on all this information, team members can formulate a detai led treatment plan.

Some patients may need to undergo one or more preliminary procedures before the treatment plan can be completed such as periodontal, endodontic and orthodontic therapy. In the course of this preparatory phase, some patients may be fou nd to be inappropriate candidates for implant reconstruction and should be treated with suitable alternatives.

In conjunction with the development of the treatment plan, it is also necessary to create a diagnostic wax -up on a duplicate of the study model to determine spatial relationships, as well as the alignment and parallelism of the implants to be placed relative to the adjacent and opposing dentition. A definitive treatment plan will be eventually formulated by the practitioner for most patients.

3) Final Treatment Considerations

Various treatment options can be presented to the patient for approval. The patient should be informed to the anticipated number of implants and whether any ancillary procedures are required. If a grafting procedure is indicated, the patient must also be aware of the various materials available for the graft. The patient should be presented with a review of the various procedures for harvesting autogenous bone, if indicated.

Patients should also be aware of whether they a re candidates for harvesting their own blood for production of platelet -rich plasma. This procedure is performed to gather a high concentration of growth factor and to ensure a successful graft outcome. The patient should be well informed about nerve repos i tioning or vestibuloplasty procedures, when deemed necessary.

The patient should be informed about whether the surgical procedure is to be performed at the dental office or an outpatient surgical clinic or whether overnight hospitalization will be required. There should also be full disclosure as to whether these procedures will be performed under local anesthesia, local anesthesia supplemented with intravenous sedation, or general anesthesia. The benefit-risk ratio of all these procedures should be presented.

The post- operative course should be carefully described to patients. They should be made aware of whether their dentures will be taken away and whether a transitional prosthesis will be provided for immediate use after surgery. Placement of immedia te provisional implants to achieve retention of a provisional prosthesis may be an option considered. In any case, patients should be informed as to how the temporary prosthesis or the lack of prosthesis will affect their appearance and their ability to fu lfill professional obligations and function in social situations. In addition, patients should be informed about the possible options of one-stage and immediate-load implants.

Written consents should be secured for both the surgical and restorative procedures. No promises or guarantees should be rendered when dealing with artificial replacements in a biological system; this fact should be clearly communicated to the patient. A full disclosure of potential complications is essential. The best course for the implant practitioner is to present the patient with global and domestic statistics for implant success rates, as documented in the literature. The individual clinician' s own experience and clinical success rates should be shared, along with some discussion of what options will likely be available in the event of an implant failure.

Full discussion of fees and methods of payment should ensue, along with a discussion of potential reimbursement by third parties and managed-care groups and the impact of such reimbursement on the patient's financial obligation.

Patients should walk away from the final consultation with a clear understanding of their post-surgical obligations such as ongoing home care. They should be given an overview of the armamentarium they will be using in this endeavor, including different types of manual and mechanical brushes, dental floss, super floss, and chemotherapeutic agents such as oral chlorhexidine antibacterial rinses. Finally, they should know what should be expected as far as returning for periodic evaluations.

Patient Selection: Oral and Systemic Considerations [15]

The bone and soft tissue response following endosseous dental implant placement is controlled by wound - healing factors, biomechanics and mineral metabolism. Because of the complexity of the tissue response, osseointegration and maintenance of endosseous dental implants may be influenced by many factors including age, diet, drugs, systemic disease, and oral disease.

Generally, endosseous dental implant may b e considered for any patient in reasonable health who desires the replacement of missing teeth and has enough bone in the area or can undergo a bone augmentation procedure. Various factors and their influence on dental implant therapy are described bel ow:

1) Physical Status

The American Society for Anesthesiology (ASA) has defined a 6 -point scale of physical status, as described previously. Endosseous implants and implant-related surgeries are restricted to PI or P2 patients. As discussed below, endosseous dental implants may be considered for some P3 patients after further patient evaluation.

2) Age

Endosseous dental implants are stationary in the jaws and do not erupt or migrate during dentoalveolar development. Younger patients may show greater crestal bone resorption around dental implants. It is therefore recommended that implant placement be delayed until growth and development have ceased or are minimal. Both dental age (eruption status of the permanent teeth) and skeletal maturation (hand - wrist radiograph) should be used to assess growth and development.

The condition of the jawbone is both age- related and site-specific. However, implant failure does not correlate with age or sex. Increasing age has no effect on osseointegration or the rat e of crestal bone resorption around dental implants. [22] Therefore, increasing age is not a barrier to successful dental implants, although medical conditions associated with increasing age may require modifications to the implant treatment plan.

3) Hypohi drotic Ectodermal Dysplasia

This condition is characterized by hypodontia, hypotrichosis, and hypohidrosis and may be autosomal or X -linked in origin. Dental implants have been used successfully in patients with severe hypodontia associated with ectodermal dysplasia.

Of interest, alveolar bone growth may continue after implant placement in the edentulous ridges of chil dren with ectodermal dysplasia, suggesting that alveolar growth is not dependent on the presence of teeth *per se*. Implant placement and prosthetic rehabilitation in young children with ectodermal dysplasia has not been found to restrict transverse or sagittal growth. However, vertical growth may result in the occasional submergence of endosseous implants, necessitating revision and placem ent of longer abutments.

4) Smoking

Many studies have shown that smoking interferes with osseointegration and accelerates bone resorption around dental implants. Smokers are at greater risk of peri - implantitis, especially in the maxilla [4,36] Shorter implants (<10 mm) have been reported to be more susceptible to failure in smokers. [4] A short-term retrospective study has shown that smoking does not play a significant role in achieving the osseointe gration of surface-modified (SLA) dental implants. [14] However, the authors have recommended more detailed and long-term studies in this regard. Smoking cessation during the healing phase following implant surgery is recommended for improved implant survival.

5) Osteoporosis

Osteoporosis is a progressive systemic disease characterized by low bone mass and deterioration of bone tissue, leading to bone fragility and fracture. The prevalence of osteoporosis increases with age and after menopause. On balance, osteoporosis appears not to influence implant survival. Moreover, endosseous dental implants may actually stimulate mandibular bone formation in a load - dependent manner.

6) Diabetes Mellitus

Diabetes mellitus is a chronic disease caused by an inherited and/or acquired deficiency in production of insulin by the pancreas or by ineffectiveness of the insulin produced. Such a deficiency results in increased concentrations of glucose in blood, which, in turn, leads to damage of many of the body's sys tems, especially the blood vessels and nerves.

In type 1 diabetes (formerly known as insulin -dependent diabetes), the pancreas fails to produce insulin. This form of diabetes develops most frequently in children and adolescents, although the incidence in later life is increasing. Type 2 diabetes (formerly known as no n-insulin-dependent diabetes) is more common and accounts for about 90% to 95% of all diabetes cases worldwide. This form of diabetes occurs almost entirely in adults

and results from the body's inability to respond properly to the action of insulin produced by the pancreas.

The ASA guidelines suggest that patients on oral agents for diabetes (P2) are suitable candidates for dental implants, whereas patients on insulin (P3) are not. Others suggest that diabetic patients who are well controlled with insulin are suitable for implant surgery under antibiotic cover and many studies have reported implant success in diabetic patients. It is concluded that endosseous dental implants are usually successful in patients with diabetes, although uncontrolled diabetes contraindicates dental implant placement. Consideration should be given to antibiotic prophylaxis for surgical procedures in diabetic patients.

7) Scleroderma

Scleroderma (systemic sclerosis) is a systemic disease that affects many organ systems. It is most obvious in the skin, which appears tight and shiny with characteristic loss of hair, decreased sweating, and loss of the ability to make a skinfold. The gastrointestinal and respiratory tracts and the renal, cardiovascular, and genitourinary systems are frequently involved. The symptoms result from progressive tissue fibrosis and occlusion of the microvasculature by excessive production and deposition of type I and type III collagens.

Oral involvement of scleroderma results in reduced denture - bearing area and changing peripheral seal. Endosseous dental implants may improve prosthesis function and comfort in these patients, although access for implant surgery and for oral hygiene may be compromised.

8) Sjögren Syndrome

Sjögren syndrome is characterized in part by dry mouth (xerostomia) and dry eyes (xerophthalmia). Xerostomia frequently results in mucositis, candidiasis, and reduced denture retention and hence is a significant concern for conventional denture wearers. Although little is known about endosseous dental implants in patients with Sjögren syndrome, implant-supported prostheses may be preferable to soft tissue-supported prostheses in these patients.

9) Multiple Myeloma

Multiple myeloma is a clonal proliferation of malig nant plasma cells in the bone marrow, which causes multiple osteolytic lesions and elevated serum immunoglobulins. Unmanaged malignant disease in general is considered a contraindication for the placement of endosseous dental implants.

10) Parkinson's Disease

Parkinson's disease is a progressive neurodegenerative disorder associated with a loss of dopaminergic nigrostriatal

neurons. Parkinson's disease is one the most common neurologic disorders, affecting approximately 1 % of individuals older than years. Cardinal features include resting tremor, rigidity, bradykinesia, and postural instability. Implant supported prostheses should be considered in patients with Parkinson's disease and other diseases affecting orofacial motor function.

11) Cytotoxic Chemotherapy

The effect of cytotoxic chemotherapy on dental implants is variable and may depend on individual immune status and the peri - implant microflora. General recommendations for patients receiving chemotherapy include:

- Thorough and regular implant hygiene
- Delaying dental implant placement following cytotoxic chemotherapy until blood values normalize.

Concurrent cytotoxic chemotherapy is associated with a high failure rate and contraindicates the placement of dental implants.

12) Bone Marrow Transplantation

Bone marrow transplantation is not a barrier to the osseointegration or survival of dental implants. Implant placement should be delayed until cytotoxic chemotherapy has ended and the marrow graft has taken.

13) Human Immunodeficiency Virus (HIV)

Although patients with AIDS may be at greater risk of peri - implantitis, endosseous dental implants have been placed successfully in HIV-positive patients. Diligent hygiene and long-term follow-up are required.

14) Systemic Drugs

Peri-implant soft t issue hyperplasia may occur in patients taking dilantin sodium or nifedipine. Careful follow - up of dental implant patients taking calcium channel blockers or other drugs associated with gingival hyperplasia is essential. Patients taking anticoagulants (including aspirin) are at risk of severe hemorrhage during implant surgery. Patients on long-term systemic corticosteroids are at risk of steroid crisis during implant surgery. Furthermore, steroid-induced osteoporosis may complicate dental implant treatment. Consultation with the patient's physician prior to dental implant placement is desirable for patients on anticoagulants or long-term systemic corticosteroids.

15) Chronically Infected Implant Sites

Periodontitis and periapical lesions should be diagnosed and treated prior to dental implant placement.

16) Oral Lichen Planus

Oral lichen planus (OLP) is a chronic inflammatory disease that presents as white striations, papules, plaques, erythema, erosions, or blisters affecting predominantly the buccal mucosa, tongue, and gingiva.

Erosive OLP has been associated with den tal implant loss, possibly because of altered capacity of the oral epithelium to adhere to the titanium surface. Surgical trauma is known to exacer bate oral lesions.

Furthermore, atrophic (eryt hematous) and ulcerative (erosive) gingival OLP lesions benefit from intensive oral hygiene, suggesting that dental implant hygiene is crucial in OLP patients.

Endosseous dental implants may be used in patients with nonerosive forms of OLP, although patients should be warned of possible lesion exacerbation related to surgery and possible implant failure if gingival lesions become erosive. As discussed below, OLP is associated with a slightly increased risk of oral squamous cell carcinoma. In this context, alternatives to dental implants may be preferable in patients with OLP.

17) Head and Neck Radiotherapy

Radiotherapy results in xerostomia, mucositis, and oral mucosal atrophy. Hence, an implant-supported prosthesis may be preferable to a soft tissue- supported prosthesis following head and neck radiotherapy.

The failure rate of endosseous dental implants in irradiated jawbone can range up to 30%. Implant placement following radiotherapy is associated with a significant risk of osteoradionecrosis, especially with irradiation above 50 Gy. Some authors have recommended a 6 - to 12-month recovery period after irradiation prior to dental implant placement. Others have suggested that immediate dental implant placement can reduce the number of surgical procedures. Presurgical hyperbaric oxygen may reduce the dental implant failure rate in irradiated jawbone from 60% to 5%.

Whatever the method, if endosseous implants are placed in irradiated jawbone, strict long- term follow- up is required to monitor the condition of the peri- implant tissues. Similarly, head and neck irradiation following dental implant place ment carries a significant risk of osteoradionecrosis. If irradiation is to be performed in areas where titanium implants have been placed, it is recommended that all prostheses, frameworks and abutments be

removed before irradiation. Osseointegrated implants can remain in situ, although they should be covered with skin or mucosa.

18) Oral and Premalignant Lesions

A proportion of benign oral mucosal lesions undergo malignant transformation. These include submucous fibrosis; oral lichen planus; dyskeratosis congenita; chronic hyperplastic candidiasis; epithelial dysplasia; actinic cheilitis; and proliferative verrucous leukoplakia

The effect of dental implants on oral premalignant lesions is unknown. However, squamous cell carcinoma arising around endosseous dental implants has been reported and dental implants may interfere with oral radiotherapy. In addition, head and neck irradiation following dental implant placement carries a significant risk of osteoradionecrosis. Hence, alternatives to dental implants may be preferable in patients with oral premalignant lesions.

19) Oral Cancer Risk

Alternatives to dental implants may be preferable in patients at increased risk for oral cancer due to reasons stated above.

Endosseous dental implants are used extensively in reconstruction following oral cancer therapy. However, approximately 2 % to 3 % of oral cancer patients develop a second primary cancer each year after removal of the primary tumor, and 90% of recurrences become manifest within 2 years of oral cancer treatment. With advances in oral cancer therapy, more patients survive initial tumors. Hence, the incidence of second primary oral cancers is expected to rise. Therefore, in certain situations it may be appropriate to delay implant reconstruction for 2 years following oral cancer treatment.

20) Tardive Dyskinesias

Tardive dyskinesias are involuntary movements of the tongue, lips, face, trunk, and extremities that occur in patients treated with long- term dopaminergic antagonist medications (schizophrenia or bipolar disorders treated with antipsychotic medication).

Orofacial dyskinesias appear as involuntary, repetitive, and stereotyped facial grimacing, lip smacking, lip puckering, chewing, sucking, tongue writhing, tongue protrusion, or jaw opening and closing. Alternatives to endosseous dental implants should be considered for patients with neurologic disorders including orofacial dyskinesia, trigeminal neuralgia, or orofacial dysesthesia.

Patient Selection

The following approach is suggested when assessing patients for endosseous dental implants:

1) Obtain a medical history (Table 2).
2) Obtain an oral and perioral history (Table 2).
3) Discuss smoking, alcohol, and diet.
4) Identify familial diseases – cardiovascular disease, cancer, autoimmunity, other.
5) Perform a thorough clinical and radiographic oral examination to identify candidiasis, hyperplasia, other mucosal disorders, benign tumors, jaw cysts, root remnants, periodontitis, periapi cal lesions, and other jaw pathology.
6) Obtain a specialist opinion for oral or systemic disease prior to dental implant placement. Seek multiple opinions if necessary.
7) Record oral and systemic changes following dental implant placement.
8) Record changes in oral and systemic diseases following dental implant placement.
9) Report oral and systemic changes to a central register.

Table 2: Simplified History for Implant Candidates

Medical History

- Allergies – drugs, local anesthetic solution, metals
- Bleeding disorders
- Drugs, depression, or diabetes
- Epilepsy
- Cardiac infarct or bypass,
- Endocarditis, rheumatic fever, mitral valve prolapse, heart valve prosthesis, or heart murmur
- Radiotherapy – head and neck
- Pregnancy
- Medical care for hospitalization

Oral and Perioral History

- Oral mucosal disease
- Jawbone disease
- Head and neck cancer
- Orofacial trauma
- Temperomandibular joint disease
- Salivary gland disease
- Maxillary sinus disease
- Uncontrolled periodontitis
- Trigeminal neuralgia, orofacial dyskinesia and dysesthesia

Radiographic Assessment: Decision Making Criteria [8]

An acceptable clinical examination and an appropriate radiographic examination are mandatory prior to every implant surgery. Diagnostic imaging and techniques help develop and implement a cohesive and comprehensive implant treatment plan. The purpose of implant imaging is to provide accurate and reliable diagnostic information on the patient's anatomy at the proposed implant sites.

Current radiation protection regulations are based on justification and the ALARA principle (as low as reasonably achievable). This implies that every radiographic examination must be carried out to the benefit of the patient by application of the lowest possible dose. Therefore, the selection of imaging technique is already part of radiation protection measures.

Significance of Surgical Complications

A reliable estimate of bone width is essential for uncompromised implant placement. Complications may arise from individual patterns of atrophy and remodeling of the maxilla and mandible after tooth loss, altering the topographic location of vital

structures in distance and course relative to the bone. The anatomic and topographic structures pertinent to implant therapy are summarized as follows:

Table 3: Important anatomical structures.

Important Anatomical Structures	**Maxilla**	**Mandible**
Anterior region	• Canine fossa • Nasopalatine nerve	• Mental fossa • Minor vessels, muscles
Premolar region	• Sinus	• Sublingual artery • Submental artery • Mental rami from submental artery
Molar region	• Sinus	Submandibular fossa • Facial artery • Tonsil rami form ascending pharyngeal artery • Lingual nerve • Mylohyoid nerve

As evident, in the maxilla, no vital structures other than the nasopalatine nerve and small vessels can be injured during surgery. Here, most of the problems arise from widely varying patterns of atrophy. Hence, a lateral perforation or a sinus perforation may be encountered, and if poor bone quality is combined with a severe perforation, insufficient primary stability of the implant may occur.

In the mandible, however, the situation becomes more complex, because injury may occur not only to structures within the bone, such as the inferior alveolar nerve, but also to soft tissu es after a lingual perforation.

In the premolar region and sometimes even in the canine region, the sublingual artery, the submental artery, and the mental rami of the submental artery take a course close to the mandible. In the molar region, the facial artery, the tonsil rami from the ascending pharyngeal artery and the lingual and mylohyoid nerves are vital structures within reach of a perforating bur. Hemor rhage in the floor of the mouth can be a severe and life -threatening situation because it extends into the oropharynx, and the surrounding soft tissues provide no self-tamponing effect. This may require acute tracheotomy and/or nasotracheal intubation.

These anatomic and topographic considerations emphasize the need for a comprehensive radiographic evaluation of the patient seeking implant therapy.

Imaging Techniques in Implant Dentistry

Imaging modalities are categorized as being essentially analog or two-dimensional and three-dimensional in view:

1) Analog or Two-Dimensional

- Periapical radiography
- Occlusal radiography
- Cephalometric radiography
- Panoramic radiography

2) Three-Dimensional

- Conventional tomography
- Computed tomography
- Magnetic resonance imaging

Periapical Radiography

Periapical radiographs provide the required contrast, resolution, and delineation of objects and are useful high - yield modalities. Although absence of the screen requires a dose higher than otherwise necessary, the effective dose and biologic risk for the patient from an E-Speed periapical radiograph in the molar region is still 5 times lower than that of a panoramic radiograph.

Conventional periapical and digital radiographs have been found to be more accurate than orthopantomography in the assessment of peri-implant bone loss. [31] Digital radiography is particularly convenient; the computer can be used to define the 2 reference points and measure the bone loss automatically; thus increasing measurement accuracy.

However, periapical radiographs have a limited overview and are unable to depict the third dimension of bone width. Moreover, they are not accurate enough in determining bone density because the lateral cortical plates prevent accurate interpretation and differentiation of subtle trabecular bone changes . Thus, a periapical radiograph appears to have a restricting disadvantage because it could lead to incomplete radiographic findings important for the treatment of implant patients.

Panoramic Radiography

The great advantage of panoramic radiography is the broad overview provided. Pathologic changes, other than caries, in regions not assigned for implant placement, can be detected and treated, which corresponds with the philosophy that implant treatment should be carried out only in patients undergoing comprehensive dentistry.

Because it is a survey radiogram, panoramic radiography allows for assessment of structures such as the maxillary sinus or the course of the mandibular canal, and it provides the possibility for vertical measurements with sufficient accuracy if the magnification factor of the panoramic x-ray unit is known.

In addition, the better overview helps to indicate the need for intraoral x-rays for questionable sites to elucidate details. For instance, to judge the periodontal situation of neighboring teeth in an implant recipient site, the sharper delineation of a periapical radiograph may be necessary. However, the need for additional intra-oral radiographs can be significantly reduced when a panoramic device is used which provides better image quality because of optimized layer thickness.

Thus, to achieve a comprehensive examination, panoramic radiography should be performed as a standard radiographic examination in partially edentulous and completely edentulous patients. Subsequently, periapical radiographs will help to elucidate details from objects not clearly visible in the panoramic radiograph. In patients in whom determination of the bone width is possible by clinical findings, these imaging techniques may remain the only radiographs necessary for treatment planning.

Limitations of panoramic radiographs include its inherent magnification and distortion factor and inability to depict bone width. The maxillary anterior region is often the most distorted region and is difficult to evaluate because of the curvature of the alveolus and the inclination of the bone.

One should be aware of the variation in the course of the inferior alveolar nerve (IAN) as i t runs through the jaw. In some patients, the canal rises gently but progressively as it is traced backward from the mental foramen to the lingual, in others it rises very steeply, and in yet others it hangs down in a catenary fashion, allowing more room for implants above the canal (Fig 1).

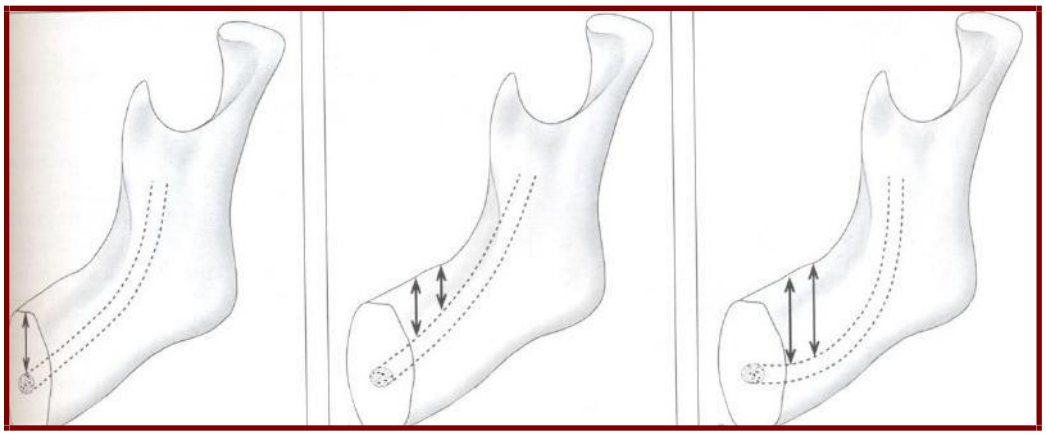


Figure 1: Variations in the course of the IAN as it runs through the mandible.

Considering the surgical importance of the location of the inferior alveolar nerve, a formula has been recommended to ascertain the available bone height above the canal on a panoramic radiograph (Fig 2). [36]

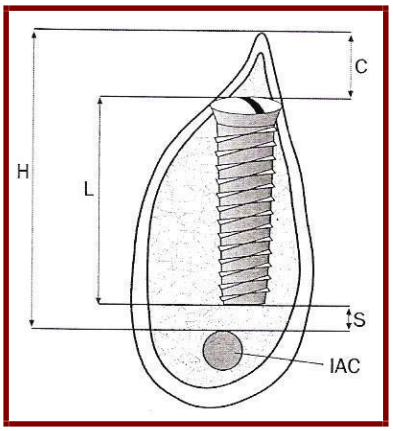


Figure 2: Permissible height of an implant may be calculated by formula $L = H/M - c - s$

If *H* is the height of bone apparently available above the canal on the panoramic radiograph, *c* is the height of "useless" bone at the crest (thin ridge of bone which is unsuitable for implant accommodation), *s* is the safety zone (normally 2 -mm), *m* is the magnification factor of the machine, and *L* is the permissible implant length, then:

$$L = H/M - c - s$$

It has been recommended that the course of the mandibular canal can be more clearly visualized by tilting th e patient's head approximately 5 degrees downward with reference to the Frankfort horizontal reference bar of the Orthopantomogram machine. [2] The author has stated that the angulation of the patients head reduced the chance of superimposition on the contralateral sides, making these structures clearly visible.

Conventional and Computed tomography

In patients in whom soft tissue structures prevent proper assessment of the jaw, the surgical site may reveal another bone volume than that expected by the preoperative examination. If the clinical examination and radiographic findings with conventional imaging modalities do not provide sufficient information about alveolar process morphology, there are 2 possibilities for cross - sectional imaging of either the maxi lla or mandible, namely, conventional or computed tomography (CT).

With conventional tomography, it possible to obtain cross - sectional images that can determine bone width. Contemporary machines for panoramic radiography generally include the possibility of curved linear tomography, linear tomography, or spiral tomography.

Computed tomography uses software that performs multiplanar reformatting (CT/MPR) from axial slices, yielding cross-sectional images that are perpendicular to the curvature of the dental arch. In addition to these images, 3 to 5 reformatted image layers are shown parallel to the dental arch, wh ich are called panoramic views (Figs 3 and 4).

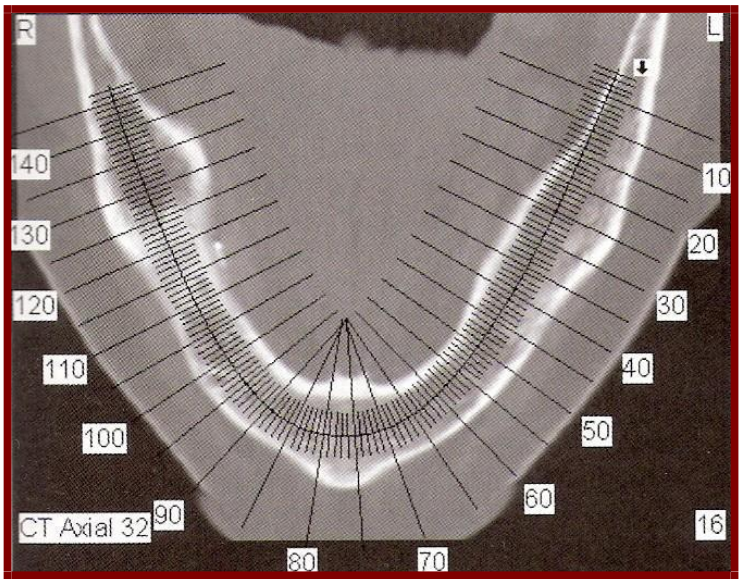


Figure 3: Computed Tomography provides reformatted cross-sectional images.

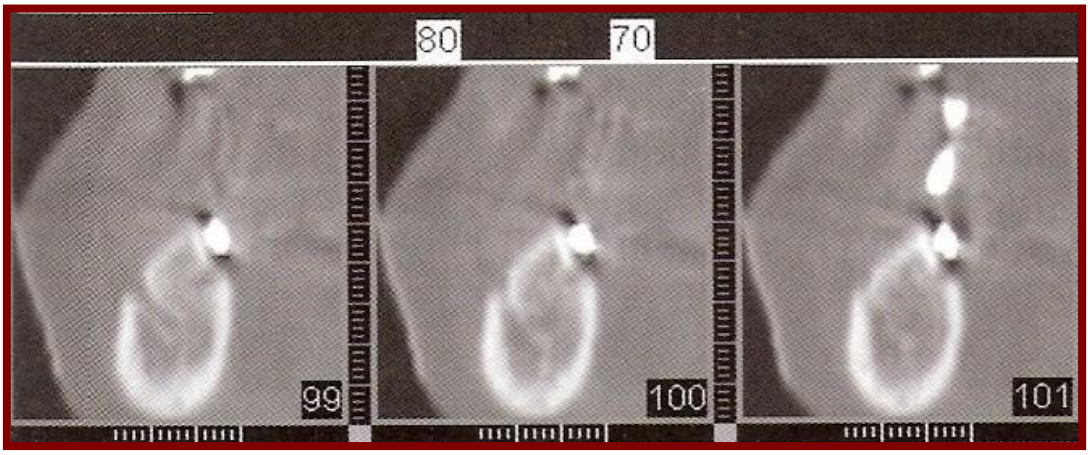


Figure 4: Axial view of alveolus

With both conventional and computed tomography, it is possible to obtain information about the width, height, and inclination of the alveolar process; anatomic and topographic structures; and to some extent, the trabecular architecture. Differences may be seen in the depiction of images, the power of object delineation, and the dose to the patient:

1) Conventional tomography provides cross - sectional images with a magnification factor of 1:1. 5 or 1: 1.75, which requires the s urgeon to scale up distance measurements with the help of templates. The perpendicular images provided by the axial slices from CT are printed life-size in alignment with a 1 - mm measuring scale on the left, providing the observer with immediate distance me asurements.

2) By the nature of image formation in conven tional tomography, a sharper central layer is superimposed by blurred objects at a larger distance from this layer. This sometimes requires good experience in object recognition. With reformatted CT images, objects seem to be better delineated. However, the microstructure seems to be worse, and faint objects are not detectable.

3) A decisive difference between conventional and computed tomography is that conventional tomography generally applies a lower dose of radiation to the patient. The dose involved in conventional tomography is about 80% that of CT. If methods for dose reduction in CT are applied, the dose to the patient can be reduced to 50% of that of conventional tomography when the complete maxilla or mandible is examined. However, if an edentulous region of 1 to 3 teeth is examined, the dose from conventional tomography is smaller than that from CT with dose reduction.

Decision-Making Criteria

Recommendations for the application of imaging techniques should be based on clinical necessity. This is based on:

- The need for portrayal of anatomic or topographic conditions (dependent to a great extent on t he experience of the surgeon).
- Ease of image production.
- Information expected from the image.
- Biologic risk for the patient (especially for young patients).
- Financial considerations.

The hypothetic mortality risk from dentomaxillofacial radiology may be put in perspective by comparing it with the hypo - thetic mortality risk of general radiologic imaging techniques. The risk from dental radiology may be the lowest in medical radiology. However, the risk from maxillofacial radiology is compa rable to the risk from conventional exposures in general radiology.

For this reason, a classification has been proposed regarding when to perform cross-sectional imaging. This classification is founded on weighing the need for an accurate assessment of the anatomic and topographic structures against the risk of harm to the patient from radiographic examination. For this purpose, the maxilla and mandible are classified into the following regions:

- Class 1: Anterior segments in the maxilla (from canine to canine)
- Class 2: Posterior segments distal to the canine in the maxilla
- Class 3: Anterior segments in the mandible (from canine to canine)
- Class 4: Posterior segments distal to the canine in the mandible

These 4 different regions gain clinical importance when taking into account the anatomic and topographic structures related to them. It can be clearly seen that more vital structures are located in the mandible, which establishes a relationship between frequency of injury and the floor of the mouth.

Thus, one could argue that in the mandible, cross -sectional imaging should be mandatory. However, if this recommendation is followed, the radiation burden would increase considerably and at times unnecessarily because implant placement is always dependent on the skill and experience of the implant surgeon and his or her ability to manage the soft ti ssues. Therefore, as a principle, cross -sectional imaging should be performed only in special cases for reasons of treatment planning. Generally, the radiographic evaluation of implant patients should be carried out according to the following 3 axioms:

Axiom No 1: General Considerations

A distinction should be made between treatment planning and follow- up. Prior to implant placement, it se e ms appropriate to consider panoramic radiography as a standard radiographic examination because it provides a low biologic risk while giving an excellent survey and an accurate means of determining implant length in both the maxilla and mandible. Periapical radiographs may be used to complete the findings in regions not sharply depicted in the panoramic radiograph.

Considering the dose involved, intraoral radiography may be considered as the standard radiographic examination during follow - up, particularly for implants in the anterior region of the maxilla, or for scientific studies. In situations where more than 5 periapical images are required, panoramic radiography may be used instead.

Axiom No 2: Application for Cross-Sectional Imaging

In the maxilla, cross-sectional imaging should be used:

- in patients with severe bone loss in the alveolar process, together with signs of enlargement of the incisor canal in the periapical radiograph, for single implants in the incisor region, or multiple implants in the incisor and canine region;
- in sites with severe bone loss and close proximity of the maxillary sinus; and

- in patients in whom a fixed prosthesis in the completely edentulous maxilla is planned.

In the mandible, cross-sectional imaging should be used when a fixed prosthesis in the completely edentulous mandible is planned.

Axiom No 3: Optional Applications for Crass-Sectional Imaging

In both the maxilla and mandible, conventional or computed tomography can be used where it is impossible to assess bone volume by means of clinical examination because of unfavorable soft t issue conditions. In the mandible, it can be employed either in patients with a pronounced mylohyoid line and submandibular fossa or other distinct anatomic undercut, or when inter - foraminal implantation is planned for atrophy corresponding to Cawood and Howell level V/ VI. From a radiobiologic point of view, conventional tomography should be preferred whenever possible for single-tooth gaps and extended edentulous spaces up to a quadrant.

Diagnostic Casts

Diagnostic casts or study models are essential to help guide both the preimplant and treatment phases of implant therapy. Many patients have been partially edentulous for an extended period of time. The combination of continued bone loss and dentition changes related to missing teeth greatly increases the factors that must be considered for oral rehabilitation with implants.

Diagnostic casts enable these prosthodontic factors to be evaluated in the absence of the patient. Other uses are:

- Assist with implant site selection and angulation requirements during the surgical phase. Surgical templates are often designed from the diagnostic casts after a diagnostic wax- up of the desired restoration.
- Permit an open discussion of treatment with other practitioners and laboratory technicians for consultation
- One set of casts may be used as a permanent record of pretreatment conditions for medico-legal purposes.
- May be used to motivate the patient' s acceptance of the proposed treatment.

The following factors need to be assessed while stu dying the diagnostic cast:

- Number of missing teeth
- Relationship of edentulous region to adjacent teeth and opposing arches
- Available bone volume
- Opposing dentition and interarch space
- Maxillomandibular relationships
- Existing occlusion: maximum intercuspation position, centric relation occlusion, occlusal scheme (canine or mutually protected, occlusal planes), premature contacts.
- Arch form and asymmetry
- Arch location of future abutments
- Occlusal wear
- Direction of forces on future implant sites
- Potential future occlusal schemes
- Potential natural abutments

Bone Mapping Procedure

The diagnostic casts can be used to estimate the underlying bone volume. The patient is first anesthetized at the proposed implant site. A needle is inserted through the overlying mucosa over the crest and facial and lingual aspects to measure its thickness. The edentulous region of the diagnostic cast is then sectioned

perpendicular to the ridge. The diagnostic cast cross -section is shaded with a pencil to represent the tissue thickness observed while probing. The remaining cross-section of the cast roughly estimates the available bone volume under the soft tissue.

Alternatively, a bone caliper with sharp beaks may be used to penetrate the soft tissues at a known height. Once the calipers are inserted, bone width can be measured by the calibrated instrument.

Diagnostic Templates

A) Computed Tomography

Although CT procedures can identify the available bone height and width accurately at a proposed implant site, the exact position and orientation of the implant (which many times determine the actual length and diameter of the implant) often are dictated by the prosthesis. A diagnostic template is most beneficial with this imaging technique.

Types of Diagnostic templates

- Vacuform template
- Acrylic template
- Template with radiopaque denture teeth

1) Vacuform template

This is produced by a vacuform reproduction of the diagnostic cast and has a number of variations:

- The proposed restoration on the diagnostic wax - up is coated with a thin film of barium sulfate prior to fabricating th e template. Although the restoration becomes evident in the CT examination, the ideal position and orientation of the proposed implant is not identified by this design.
- The proposed restoration sites in the vacuform of the diagnostic wax- up are filled with a blend of 10% barium sulfate and 90% cold cure acrylic. This results in a radiopaque tooth appearance of the proposed restorations in the CT examination, which matches the density of enamel and dentin of natural teeth. However, the exact position and orientation of the implant is not identified.
- The previous design is modified by drilling a 2 mm channel through the occlusal surface of the proposed restoration using a twist drill. This corresponds to the ideal position and orientation of the implant and i s identified on CT examination.

2) Acrylic template

An acrylic template is obtained from the diagnostic wax -up. The template can be modified by coating the proposed restorations with a thin film of barium sulfate and filling a hole drilled through

the occlusal surface of the restoration with gutta -percha. The surfaces of the proposed restoration then become radiopaque in the CT examination, and the position and orientation of the proposed implant site may be identified by the radiopaque plug of gutta -percha.

3) Template fabricated with radiopaque denture teeth

These radiopaque denture teeth are specifically manufactured for implant imaging purposes and are used for the diagnostic wax -up and subsequently are incorporated into the template. If acceptable, it may be modified into a surgical template at a later stage. This serves to transfer these findings to the patient at the time of surgery (Figs 5 and 6).

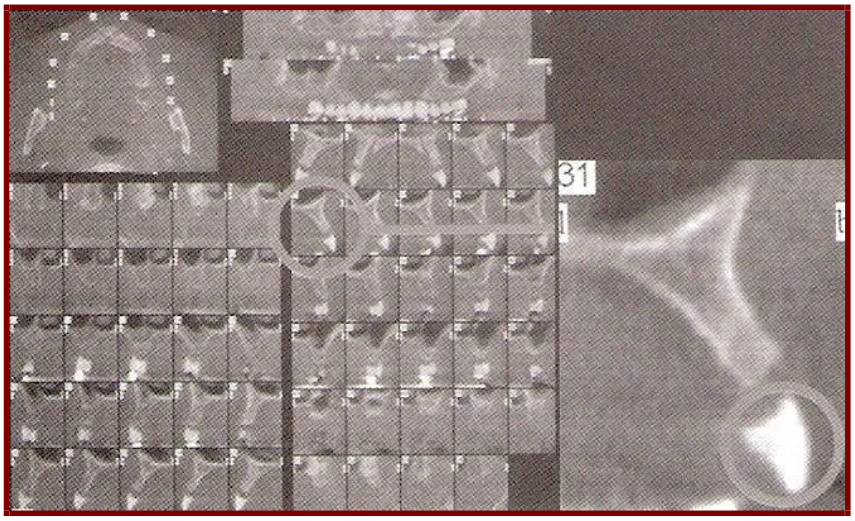


Figure 5: The contours of the teeth are clearly visible and highly opaque to facilitate image interpretation.

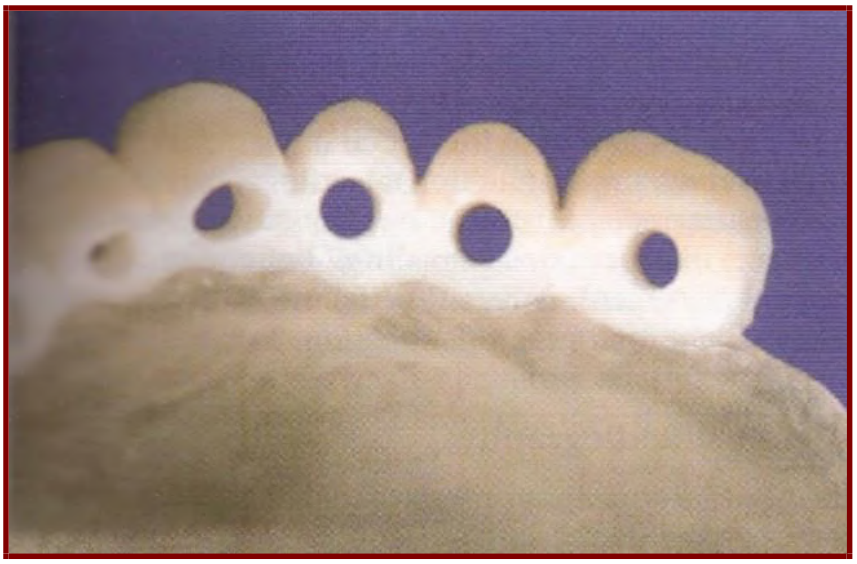


Figure 6: The radiographic template can be easily transformed into a surgical guide.

B) Complex Tomography

Diagnostic templates for tomography examinations are generally less precise than those required in CT examinations.

- The simplest tomography template is produced by obtaining a vacuform of the diagnostic cast with 3 -mm ball bearings placed at the proposed implant positions. A number of tomograms of the implant region are produced with the implant site identified by the one in which the ball bearing is in sharp focus. The ball bearings additionally can serve as a measure of the magnification of the imaging system.
- Templates that incorporate metal cylinders or tubes at the proposed implant sites can also be used.

- A vacuform template of the diagnostic cast with barium coating of the proposed restoration and orthodontic wires to indicate the position and orientation of the proposed implant, can also be used and provides the most diagnostic information of the templates described.

C) Panoramic Radiography

A diagnostic template can be used with panoramic radiographs to assess the amount of magnification. 5 -mm ball bearings or wires are incorporated around the curvature of the arch while fabricating the template. The amount of magnification can subsequently be determined in the radiograph which helps in off-setting the inherent inaccuracy in this technique (Fig 7).

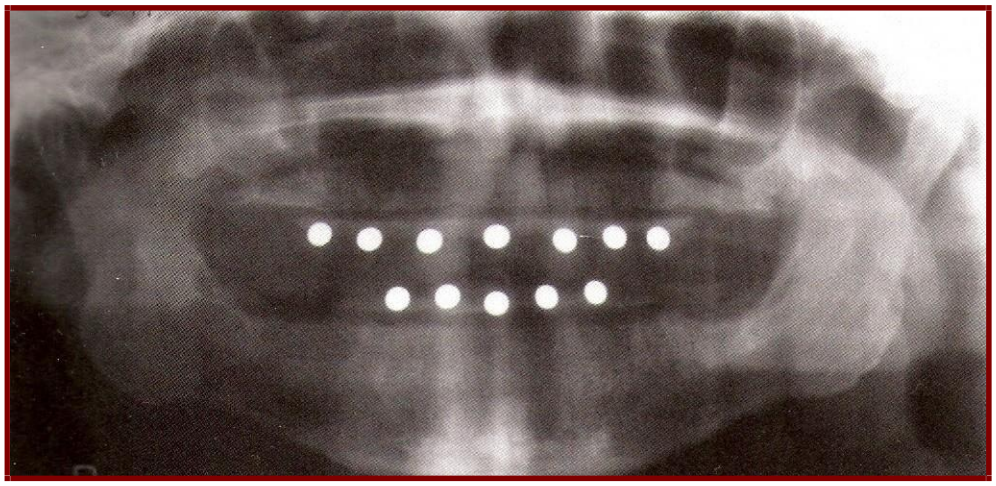


Figure 7: Panoramic radiograph with 5-mm ball bearings on the crest of a Division A mandible. The magnification of the radiograph can be calculated.

Prosthetic Options in Implant Dentistry

Implant dentistry is unique because additional foundation units may be created for a desired prosthodontic result. Thus, a range of treatment options are available to most partially and completely edentulous patients.

In the past, greater emphasis has been placed on the bone available for implant insertion which determines the position and number of implants and, consequently, the final prosthesis design. However, the implant treatment plan of choice is both patient and problem centered and requires a shift in this traditional approach. The benefits of implant dentistry can be realized only when the full range of available options for the final prosthesis is first evaluated by the practitioner and then presented to the patient.

Thus, it is important to first visualize the intended final prosthesis based on which the existing bone is evaluated to determine the type and number of implants necessary to support the intended prosthesis.

In 1989, Misch proposed five prosthetic options available in implant dentistry as given below (Figs 8 and 9):

Table 4: Prosthodontic Options

Type	Definition
FP-1	Fixed prosthesis which replaces only the crown and appears like a natural tooth.
FP-2	Fixed prosthesis which replaces the crown and a portion of the root. Crown contour appears normal in the occlusal half but is elongated or hyper contoured in the gingival half.
FP-3	Fixed prosthesis which replaces missing crowns and gingival colour and portion of the edentulous site.
RP-4	Removable prosthesis which is mainly an overdenture completely supported by implants.

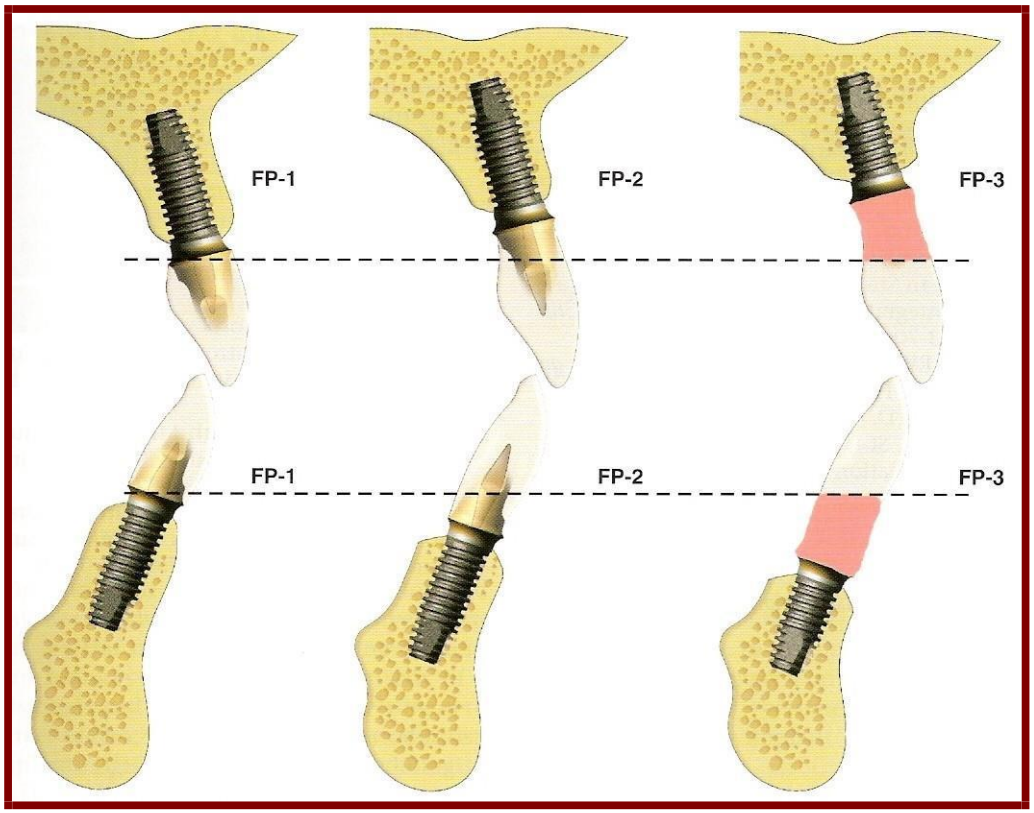


Figure 8: Fixed restorations have three categories: FP 1, FP 2, and FP 3.

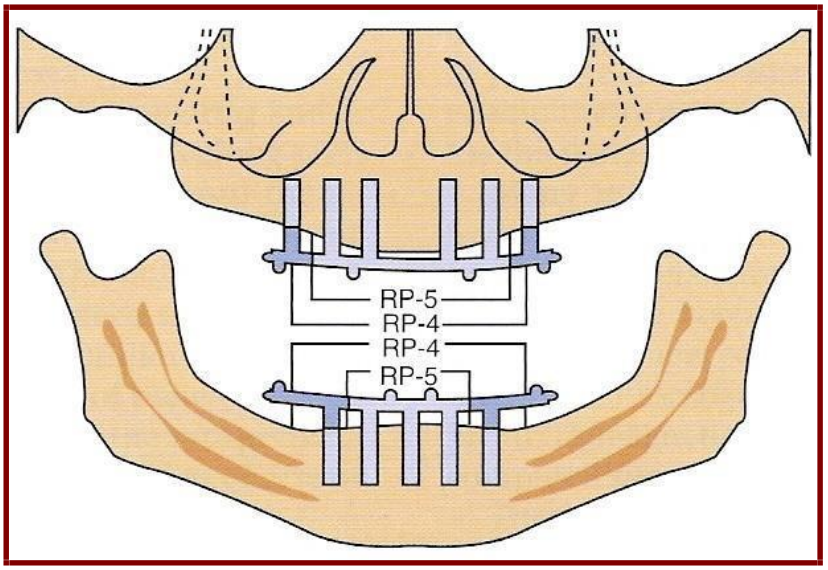


Figure 9: Removable prostheses have two categories RP-4, and RP-5 based on implant support.

FP-1 Prosthesis

This is a fixed restoration which appears to replace only the anatomical crowns of the missing natural teeth (Fig 10).

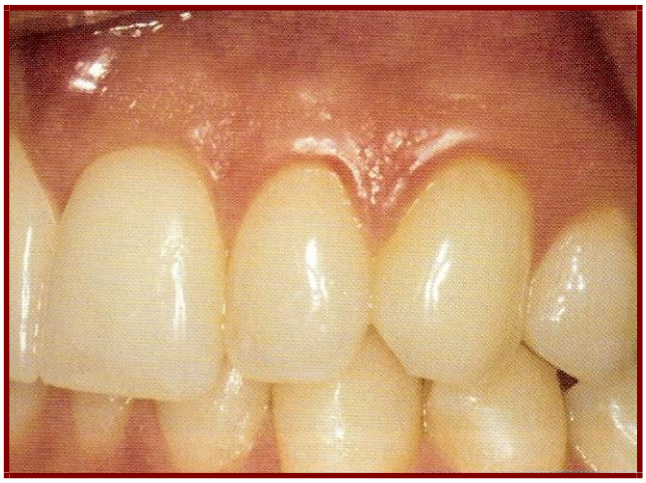


Figure 10: Intra-oral view of an FP-1 restoration replacing maxillary canine.

It is most desirable in the maxillary anterior region for esthetic purposes when the loss of hard and soft tissues has been minimal and favourable volume and position of the residual bone permit ideal placement of the implant in a location similar to the root of a natural tooth.

However, the final esthetic result in the maxillary anterior region is usually complicated by:

- Bone remodeling following tooth loss (crestal width shifts towards the palate).
- Lack of interdental soft t issue resulting in open “black” triangular spaces on smiling.

- Narrower diameter and rounder cross-section of the implant in comparison to a natural maxillary central incisor root.

Thus, for an FP-1 prosthesis in the maxillary anterior r egion, bone augmentation may be desirable before implant placement with further soft tissue augmentation after the abutment is positioned to improve the interproximal gingival contour and overall emergence profile of the restoration.

FP-2 Prosthesis

This is a fixed restoration which appears to restore the anatomical crown and a portion of the root of a natural tooth. The volume and topography of the available bone are more apical compared with the cementoenamel junction of a natural root. These restorations are similar in appearance to teeth exhibiting periodontal bone loss and gingival recession.

FP-2 prosthesis is mainly indicated if the high lip line position during smiling or low lip line position during speech does not display the cervical regions (Fig 11).

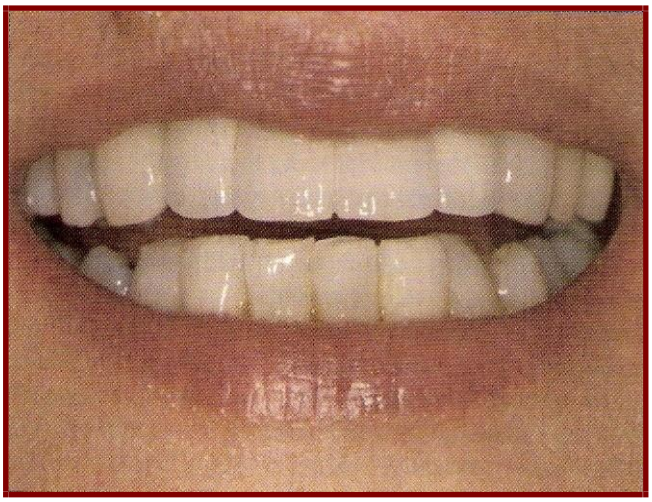


Figure 11: An FP-2 prosthesis is indicated as the high smile line does not expose the gingiva.

The restoration rarely results in ideal soft tissue contours around the emergence of the crown(s). Also, the wide open embrasures may cause food impaction and hygiene is difficult to achieve. It is important to inform the patient about these limitations prior to treatment. The maxillary FP -2 prosthesis is juxtaposed to the tissue so as not to impair speech.

Due to the greater crown height of the restoration (compared to a FP-1), the cervical region of the implant is subjected to a greater moment of force during lateral excursions or as observed with cantilevered restorations. Hence, additional implants or shorter cantilever lengths should be considered during the treatment planning phase.

In case of a multiple- unit FP-2 restoration, the mesio-distal implant position can be selected based on bone width and angulation rather than the esthetic outcome since the cervical contour is not displayed during function (Figs 1 2 and 13). However, the implant should be placed in the correct facio -lingual position to ensure that hygiene and direction of forces are not compromised.

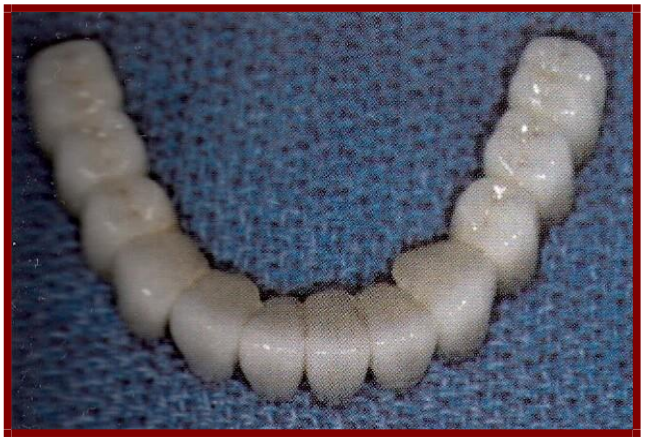


Figure 12: An occlusal view of an FP-2 complete mandibular fixed prosthesis.

.

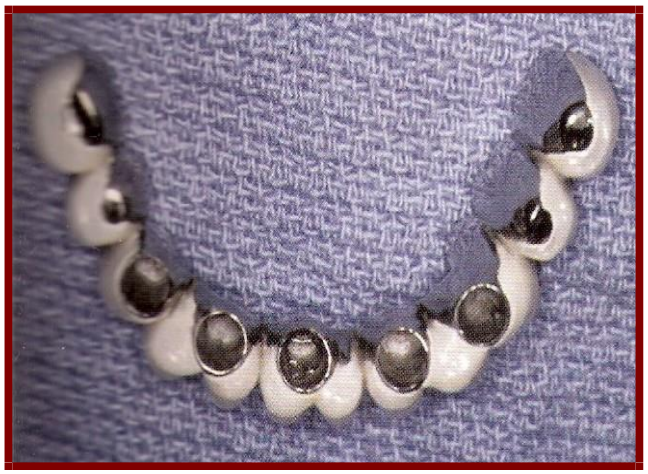


Figure 13: Almost every implant is in the interproximal embrasure

FP-3 Prosthesis

This is a fixed restoration which appears to replace the natural teeth crowns and a portion of the soft tissue. The original available bone height has further decreased by natural resorption or osteoplasty at the t ime of implant placement. The restored gingival colour of the FP- 3 gives a more natural appearance to the restoration.

The FP-3 prosthesis is indicated when the patient has a high maxillary lip line position during smiling or a low mandibular l ip line position during speech (Figs 14 and 15)

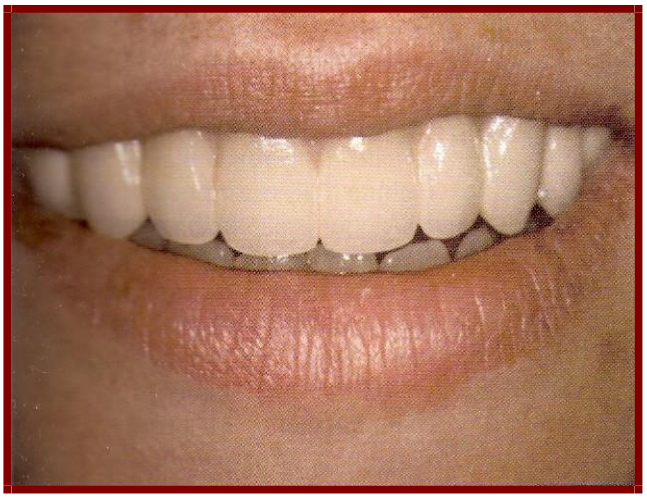


Figure 14: Exposure of gingiva during smiling necessitates an FP-3 restoration.

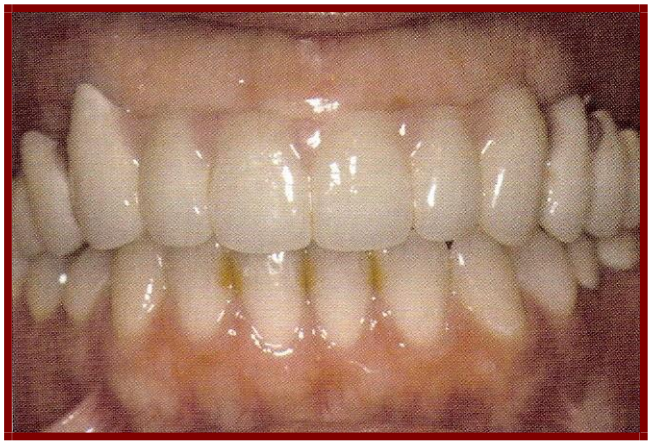


Figure 15: An FP-3 restoration replacing the interdental papillae with pink porcelain

As with an FP-2 prosthesis, the cervical region of the implant in an FP-3 restoration is subjected to a greater moment of force during lateral excursions or with cantilevered restorations and consequently additional implants or shorter cantilever lengths should be considered during the treatment planning phase.

Two approaches to an FP-3 prosthesis exist:

i) *A porcelain-metal restoration* using pink porcelain to simulate soft t issue. This is indicated in situations of less interarch space, i.e., when the crown height space from the crestal bone to the occlusal plane is less than 15 mm.

ii) *A hybrid restoration* using a metal substructure or framework with porcelain denture teeth and acrylic to join these elements

together (Fig 16). This is indicated in situations of more interarch space, i .e., when the crown height space from the crestal bone to the occlusal plane is at least 15 mm.

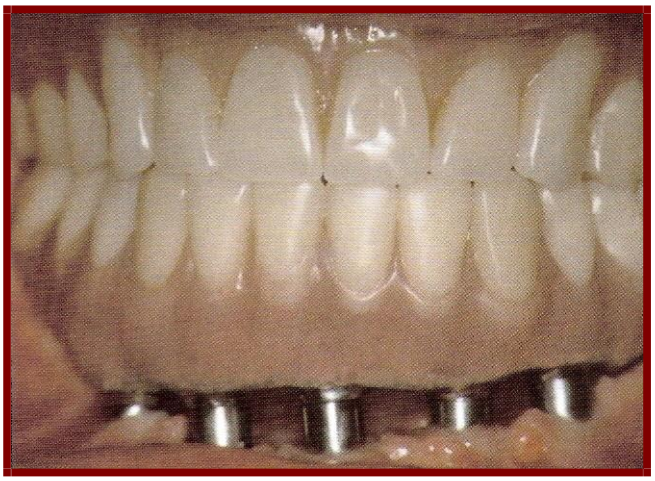


Figure 16: The hybrid prosthesis is indicated when crown height is 15 mm or greater.

Lower impact forces due to the intervening acrylic; easier soft tissue replacement; lower cost; and ease of repair are some of the advantages of a hybrid prosthesis over a porcelain -metal restoration. However, l ikelihood of repair is more due to fatigue failure of acrylic over a period of time.

RP-4 Prosthesis

This is a removable prosthesis (overdenture) which is completely supported by endosseous implants. Overdenture attachments usually connect the removable prosthesis to a low-

profile tissue bar or superstructure that splints the implant abutments (Fig 17).

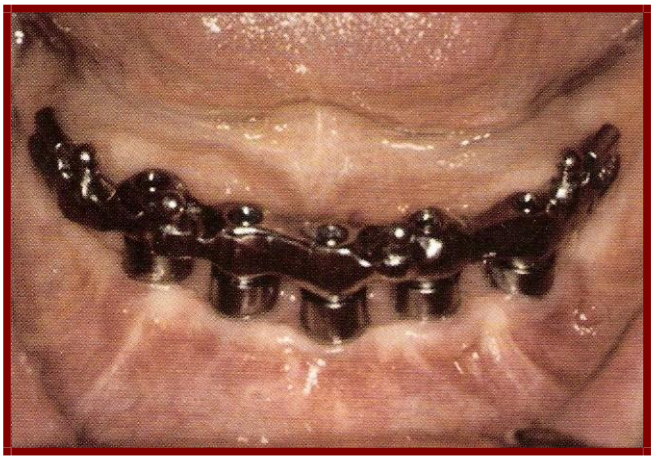


Figure 17: An RP-4 restoration is completely supported by implants.

The number of implants to provide support for the prosthesis varies and is primarily dependent on the bone quantity and quality. Usually five or six implants in the mandible and six to eight implants in the maxilla are required with a more lingual and apical implant placement compared with the implant position for an FP-1 or FP-2 prosthesis. This accommodates space for the denture teeth, bulk of acrylic, superstructure and overdenture attachments.

RP-5 Prosthesis

This is a removable prosthesis (overdenture) which gains support from both implants and soft tissue. The amount of implant support for the prosthesis varies (Fig 18).

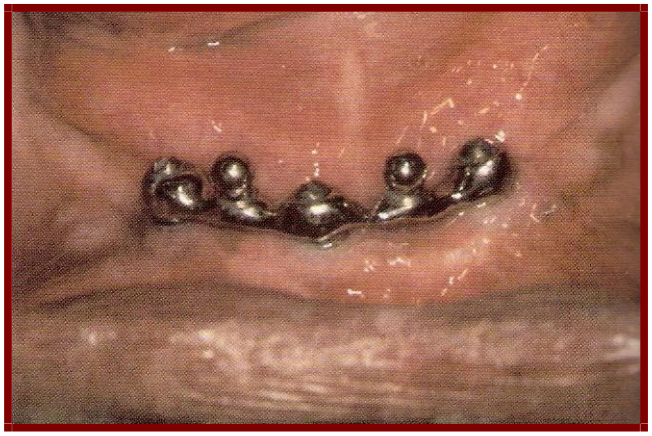


Figure 18: An RP-5 restoration gains support from both implants and soft tissue.

The primary advantage of a RP-5 restoration is the reduced cost. However, the bone will continue to resorb in the soft tissue - borne regions of the prosthesis. In fact, bone resorption with RP -5 restorations may occur 2 to 3 t imes faster than the resorption found with complete dentures. Relines and occlusal adjustments every few years are common maintenance requirements.

Available Bone: Influence on Treatment Planning

Once the final prosthesis type has been determined, the next consideration is the required size, number, and location of endosseous implants necessary to satisfy the prosthodontic requirements. The primary criterion for proper implant support is the amount of available bone and is evaluated during the clinical examination and radiographic assessment.

Definition

Available bone describes the volume of bone in the edentulous area considered for implant placement. It represents the external architecture of the bone.

Changes in Bone Volume after Tooth Loss

The amount of bone loss that occurs during the first year after tooth loss is almost 10 times greater than in the following years. A 25% decrease in bone width occurs within the first year and 40% within the first 1 to 3 years. As a result, the residual ridge shifts palatally in the maxilla and lingually in the mandible at the expense of the buccal cortical plate. Ratio of anterior maxillary bone loss to anterior mandibular bone loss is 1:4. The posterior edentulous

mandible resorbs at a rate about 4 times faster than the anterior edentulous mandible.

However, maxillary atrophy is an equal cause of concern. The original height of available bone in the maxilla is almost half that available in the mandible. In addition, the maxillary sinus expands towards the crest of the edentulous ridge after tooth loss. This further compromises the bone volume available for implant placement. In fact, the posterior maxilla bone loses volume faster than any other region and more often necessitates a bone augmentation procedure to enhance the support area.

Evaluation of Available Bone

The available bone for implant placement is evaluated in terms of the following parameters (Fig 19):

i) Height
ii) Width
iii) Length
iv) Angulation
v) Crown height / Bone Height (Implant body) ratio

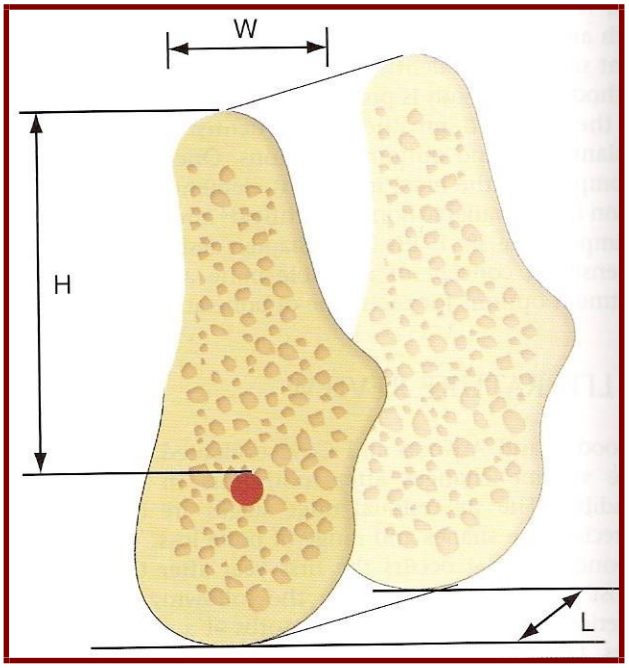


Figure 19: Available bone at the implant site is evaluated in terms of height (H), width (W), and length (L).

i) Available Bone Height

The available bone height in an edentulous site is an important consideration because it governs the selection of the height (or length) of the implant fixture. It also influences the available crown height space and, consequently, force considerations and esthetics.

The available bone height is measured from the crest of the edentulous ridge to the opposing limiting anatomical landmark during radiographic assessment (Fig 20). These limiting structures

include the inferior alveolar canal in the mandible and the floor of the nasal cavity and maxillary sinus in the maxilla.

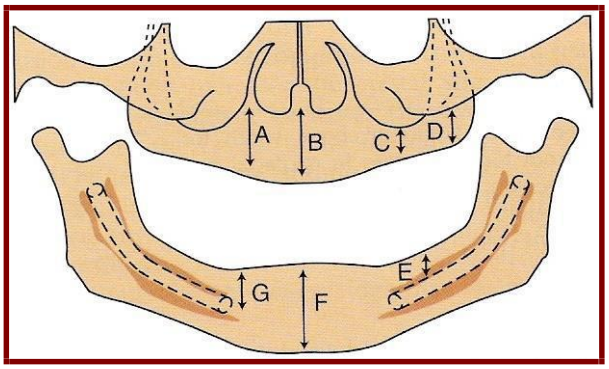


Figure 20: Height of available bone is measured from the crest of the edentulous ridge to the opposing landmark.

The anterior regions of the jaws have the greatest bone heights available. Specifically, the maxillary canine eminence region offers the greatest bone height in the maxilla and the mandibular first premolar region provides the most vertical column of bone in the mandible.

In posterior regions, opposing landmarks such as the inferior alveolar canal and maxillary sinus prove to be more limiting for implant placement. This may necessitate use of narrower and shorter implants in these regions where greater forces are routinely generated. As a result, prognosis for implants placed in the posterior edentulous regions is regarded as being more guarded in

comparison to anterior regions and the treatment plan may need to be modified to improve long term success.

A 2-mm of bone height between a critical structure (inferior alveolar canal or maxillary sinus) and the implant is considered as a guideline to guard against surgical error.

ii) Available Bone Width

The width of available bone represents the bucco -lingual dimension of available bone and determines the implant diameter. The minimum bone width is considered at the mid- facial and mid-lingual crestal region of the potential implant site since the round cross-sectional design of the implant body results in more bone in all other dimensions.

As a guideline, a minimum of 0. 5 -mm of bone should be available on each side of the implant at the crest to ensure sufficient bone thickness and blood supply around the implant. Hence, a 4- mm diameter implant usually requires more than 5 -mm of crestal bone width (Fig 21).

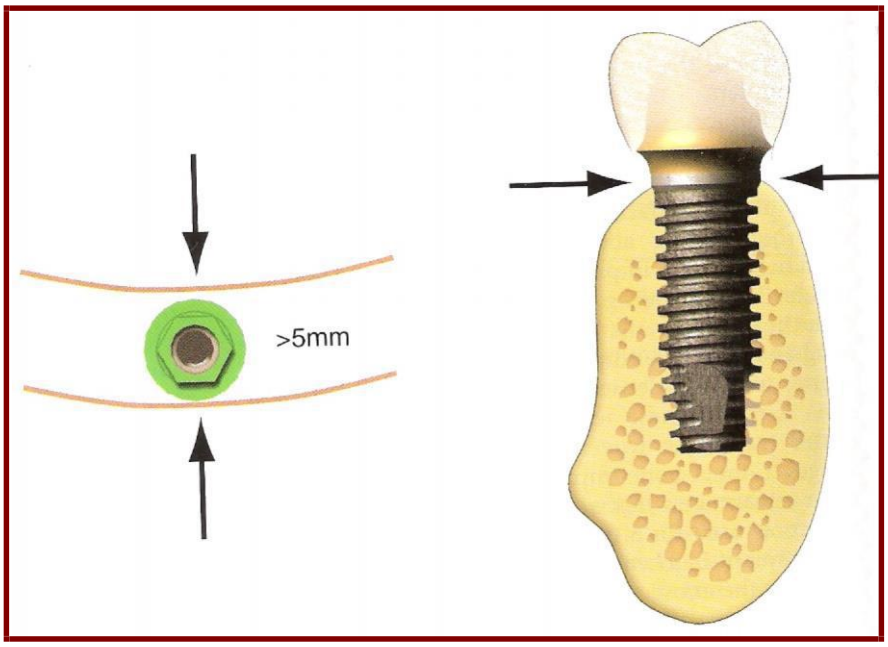


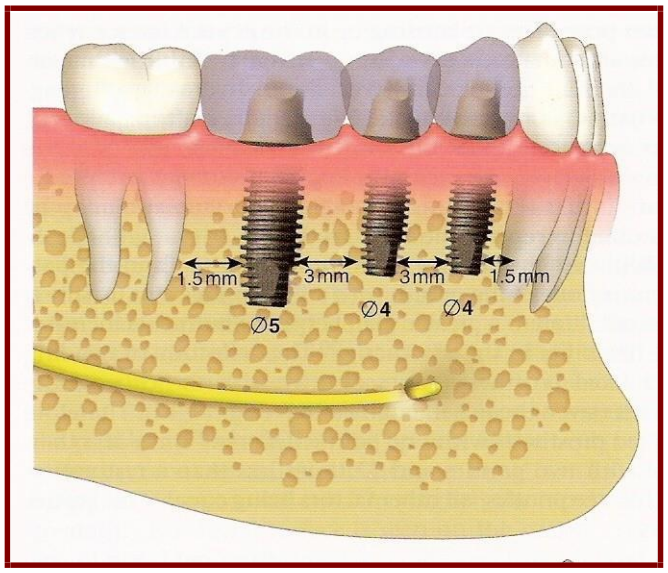
Figure 21: Minimum bone width for a 4 -mm root-form implant is 5-mm in midfacial and lingual region.

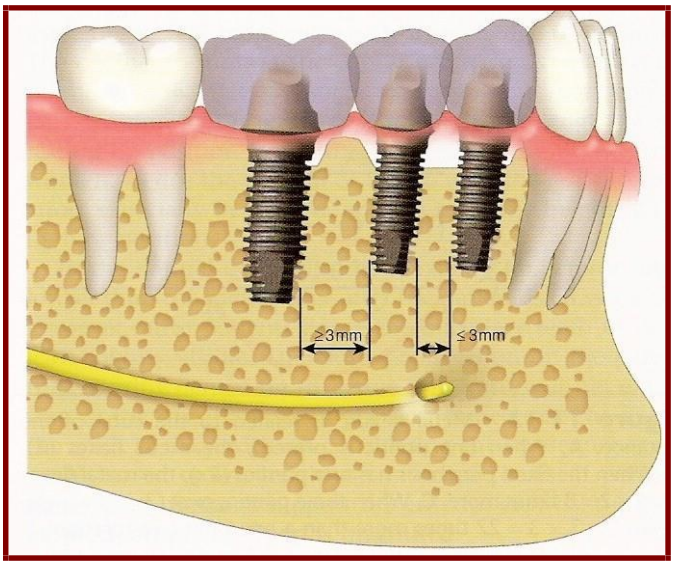
The crest of the edentulous ridge is composed of dense cortical bone which permits immediate fixation of the implant. It normally has a triangular cross-section and is supported by a wider base. Hence, an osteoplasty will provide greater width of bone, although of reduced height. However, the anterior maxilla does not follow this rule because most edentulous ridges exhibit a labial concavity in the incisor area with an hourglass configuration.

iii) Available Bone Length

This refers to the mesio-distal length of available bone in the edentulous area and is limited by adjacent teeth or implants. As a guideline, the ideal mesiodistal distance between an implant and a tooth is 1.5 mm or more and 3-mm between each implant. This is

because if bone loss occurs at the crest module of an implant or from periodontal disease with the adjacent tooth , the vertical defect will not spread to a horizontal defect and cause bone loss on the adjacent structure (Fig s 22 and 23). Thus, a 4 -mm diameter implant usually requires a minimum 7 mm of available bone length.





Figures 22 and 23: The ideal mesiodistal length between an implant and tooth is 1.5 mm or more and 3 mm between each implant.

A study has shown that placing implants in close proximity to each other (1 to 1.5 mm) does not adversely affect bone height or density. Conversely, the study showed that placing implants close together may increase bone growth. [7]

iv) Available Bone Angulation

Ideally, the bone is perpendicular to the plane of occlusion; is aligned with the forces of occlusion; and is parallel to the long axis of the tooth or restoration. The available bone angulation represents the root trajectory in relation to the occlusal plane and, therefore, signifies the direction of forces applied to the implant body.

The bone angulation does not remain constant after tooth loss. A common example is the anterior maxilla. Here, labial undercuts and resorption after tooth loss often mandate a greater angulation of the implant or correction of the site before insertion. A similar protocol may be considered in the submandibular fossa region of the posterior mandible which may show a deep lingual undercut.

iv) Crown Height / Implant body ratio

The available bone height influences the available crown height space. The crown height influences the esthetic appearance of the final restoration. Importantly, crown height may be considered a vertical cantilever and influences the amount of moment force exerted on the implant and surrounding crestal bone.

As a guideline, the crown height/implant body ratio should be ≤ 1 for improved implant prognosis. When this force multiplier is unfavorable (>1), the treatment plan may be modified to include a greater number of implants or wider implants to counteract the increase in stress.

Classification System for Available Bone

The dental implant approach to different bone volumes needs to be treatment plan oriented. In 1985, Misch and Judy proposed a classification system for the available bone with treatment options for each category. The basic four divisions have been expanded to seven categories to extend this specific organized approach. Based on the Misch-Judy classification the bone volume divisions are (Fig 24):

- Division A
- Division B
    - i) Division B +
    - ii) Division B - w (width)
- Division C
    - i) Division C - w (width)
    - ii) Division C - h (height)
    - iii) Division C - a (angulation)
- Division D

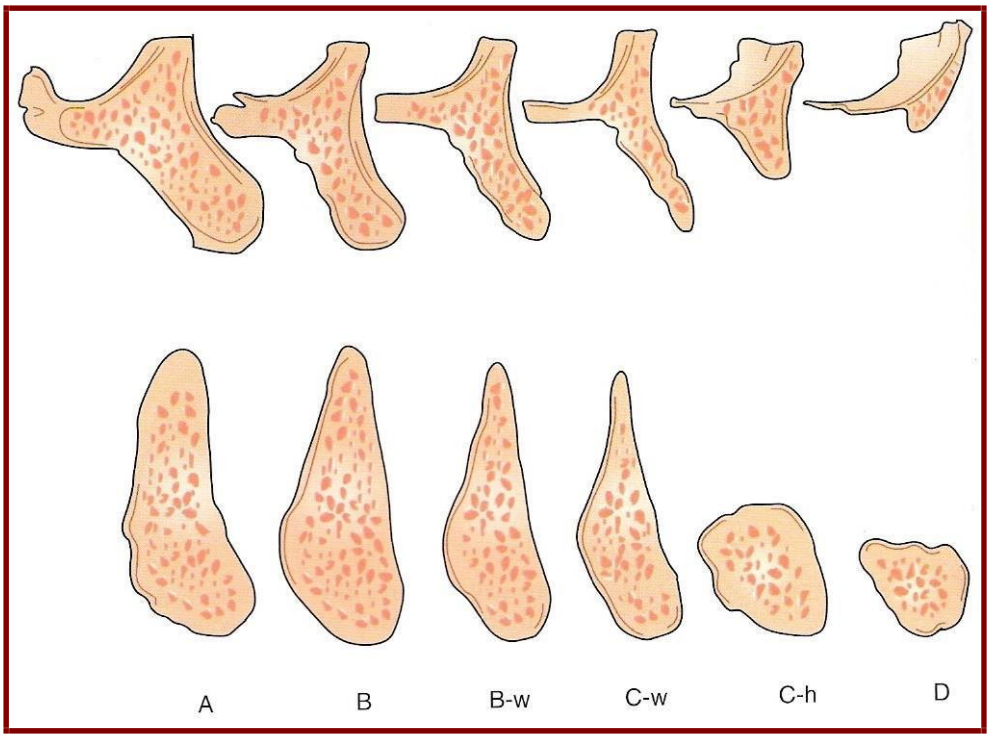


Figure 24: Classification of available bone follows the natural patterns of bone resorption in the jaws.

Division A (Abundant Bone)

This category of bone volume is available soon after tooth loss and is abundant in all dimensions.

Table 5: Division A Dimensions

≥ 12 mm height
≥ 5 mm width
≥ 7 mm length
≤ 30 degrees of angulation
≤ 15 mm crown height

Based on the available dimensions, use of Division A root-form implants with height ≥ 12 mm and width ≥ 4 mm is indicated in this category. Their advantages include:

- Greatest surface area
- Improved stress distribution
- Greatest range of prosthetic options
- Less fracture of implant and components
- Less abutment screw loosening

Division A bone is mainly observed in the anterior regions (Fig 25).

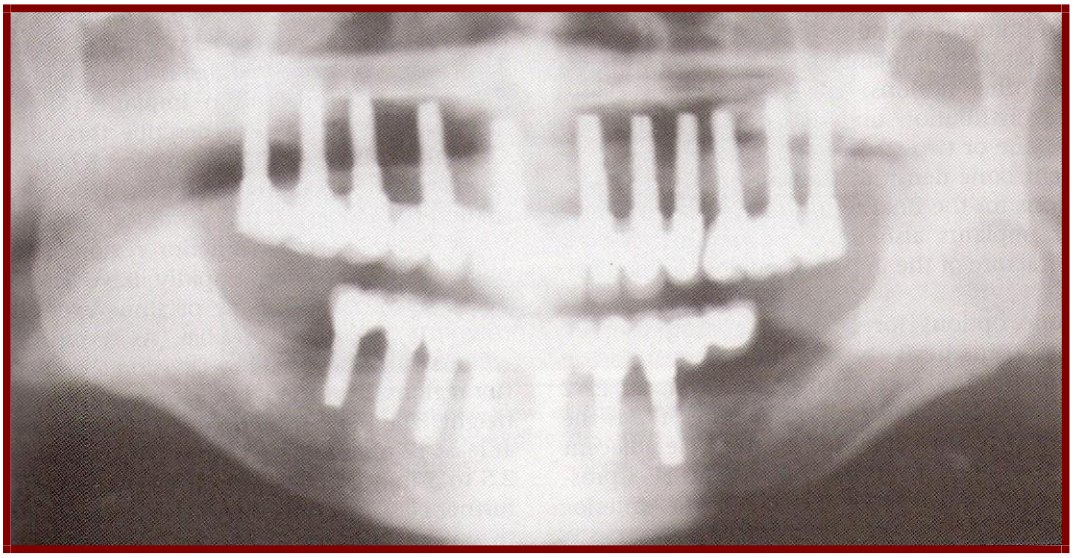


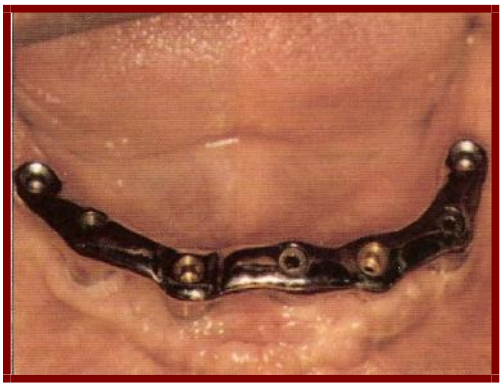
Figure 25: A panoramic radiograph of fixed maxillary and mandibular implant supported restorations in Division A bone

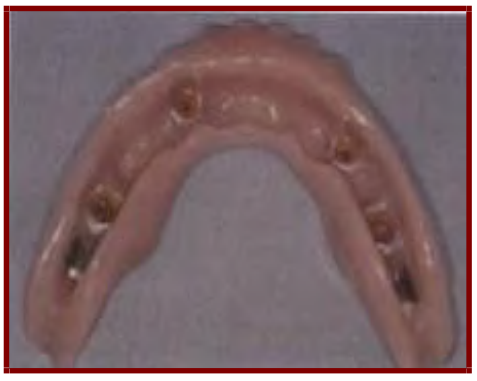
Less bone height is available in the posterior mandible and maxilla due to limiting structures. In such situations, wider implants (5 to 6 mm) may be considered in the molar regions as suitable

alternatives. Osteoplasty may be performed to obtain the necessary bone width.

Prosthetic Options Available in Div A bone

- FP-1 restorations require Div A bone to allow ideal implant placement and natural appearance of the final prosthesis.
- FP-2 or FP- 3 prosthesis may be considered depending on amount of bone loss and lip positions.
- RP-4 or RP-5 may need osteoplasty to gain sufficient interarch space to accommodate for the denture teeth, bulk of acrylic, superstructure and overdenture attachments (Fig s 26 and 27).





Figures 26 and 27: Low profile overdenture design for Division A bone. Osteoplasty may be needed.

Division B (Adequate Bone)

Slight to moderate atrophy is used to describe this clinical condition.

Table 6: Division B Dimensions

≥ 12 mm height		
width	B +	4 to 5 mm
	B – w	2.5 to 4 mm
≥ 6 mm length		
≤ 20 degrees of angulation		
≤ 15 mm crown height		

Division B bone is characterized by reduced bone width in comparison to Division A bone and is mostly observed in the posterior regions. Two subtypes (B + and B – w) exist depending on the extent of resorption. The available mesio -distal bone length and angulation criteria also differ as a consequence of the reduced width of bone. Criteria of available bone height and crown height remain the same.

Treatment Options for Div B bone

1) Osteoplasty

The most common approach followed is to modify the narrower Division B ridge into another bone division by osteoplasty.

If the bone height attained after osteoplasty is greater than 12 mm, the division has been altered to a Division A with width > 5 mm (Fig 28). A FP-2 or FP-3 restoration is indicated in this scenario to compensate for the increased clinical crown height (Fig 29). However, the crown height/ implant body ratio remains < 1 after the osteoplasty due to sufficient available bone height. Osteoplasty to obtain a Division A ridge is mainly indicated in the anterior mandible because of the abundant available bone height and fewer esthetic concerns.

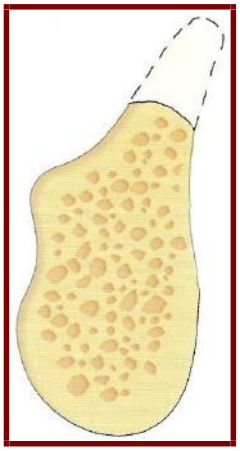


Figure 28: A Division B ridge may be converted to Division A by osteoplasty.

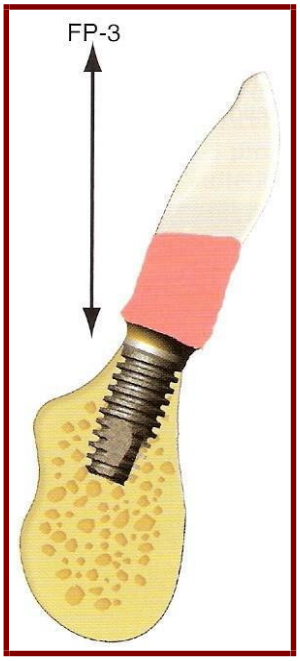


Figure 29: An FP- 3 prosthesis is usually indicated due to extended crown heights.

If bone height attained after osteoplasty is less than 12 mm, the division has been altered to a Division C – h with the crown height/ implant body ratio > 1. The treatment options will then follow those available in the Division C – h bone.

***2)* Augmentation**

The Division B ridge may be converted to a Division A by augmentation (Fig 30). The augmentation requires a 4 to 6 months healing period before placement of endosteal implants.

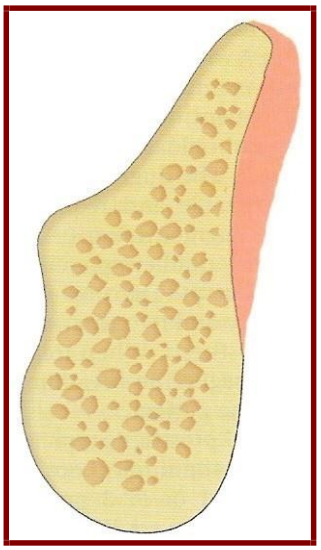


Figure 30: Alternatively, augmentation may upgrade the Division B ridge to Division A.

Augmentation is more predictable when the volume to augment is minimal and i s for width rather than height due to the greater number of osseous walls in contact with the graft material. Augmentation is mainly indicated in the anterior maxilla for esthetics since it results in improved crown height/implant body ratios and more natural looking abutments.

***3)* Insert Division B implants**

The third option is to treat the available bone volume as it is and place narrower diameter implants.

Division B implants have a smaller diameter of 2.7 to 3. 5 mm. These root-form implants are indicated mainly for anterior single-

tooth replacement for maxillary laterals or mandibular incisors. Their limitations are:

- The nearly 25% reduction in surface area result s in almost twice the stress concentration at the crestal region.
- Lateral loads result in almost thrice the stress to the implant as compared to Division A implants. Hence, a greater risk of fatigue fracture is present.
- Due to the narrow diameter of the implant the emergence profile of the restoration is less esthetic (except for maxillary lateral or mandibular incisors)

Hence, when Division B implants are indicated, it is advisable to increase the surface area by placing additional implants (wherever possible) and by surface treatments. In addition, t he angle of load must be reduced to less than 20 degrees to co mpensate for the smaller diameter.

Narrower diameter implants have been found to be successful in the anterior region of the maxilla and are preferable where space is limited. [9,32,33]

Division C (Compromised Bone)

Moderate to advanced atrophy is used to describe this clinical condition. The bone may be deficient in one or more dimensions.

Table 7: Division C Dimensions

< 12 mm height (C – h)
< 2.5 mm width (C – w)
> 30 degrees of angulation (C – a)
> 15 mm crown height

With continued resorption, the Division C – w bone changes to a Division C – h bone which is commonly observed in the posterior regions because the maxillary sinus or mandibular canal limits the vertical height sooner. Division C – a bone is found most often in the anterior maxilla and mandible with facial undercut regions, or the mandibular second molar with a severe lingual undercut. Implant-supported prostheses are more complex for this category due to the reduced bone volume but the patient usually is in greater need for increased prosthodontic support.

Treatment Options for Division C Bone

A) Division C – w

1) Osteoplasty

This converts the Division C – w bone to a Div C – h category since the crown height/implant body ratio is > 1. The treatment protocol of Division C – h bone is then followed.

2) Augmentation

Augmentation of Division C – w bone is done when a fixed restoration is desired or when force factors necessitate so . The edentulism is then treated with the options available in the division of bone attained after augmentation. Augmentation is preferred in the posterior maxilla or mandible since osteoplasty may result in a Division D bone which represents the poorest prognosis.

B) Division C – h

1) Augmentation

This is advocated in the posterior maxilla and mandible (Figs 31 and 32).

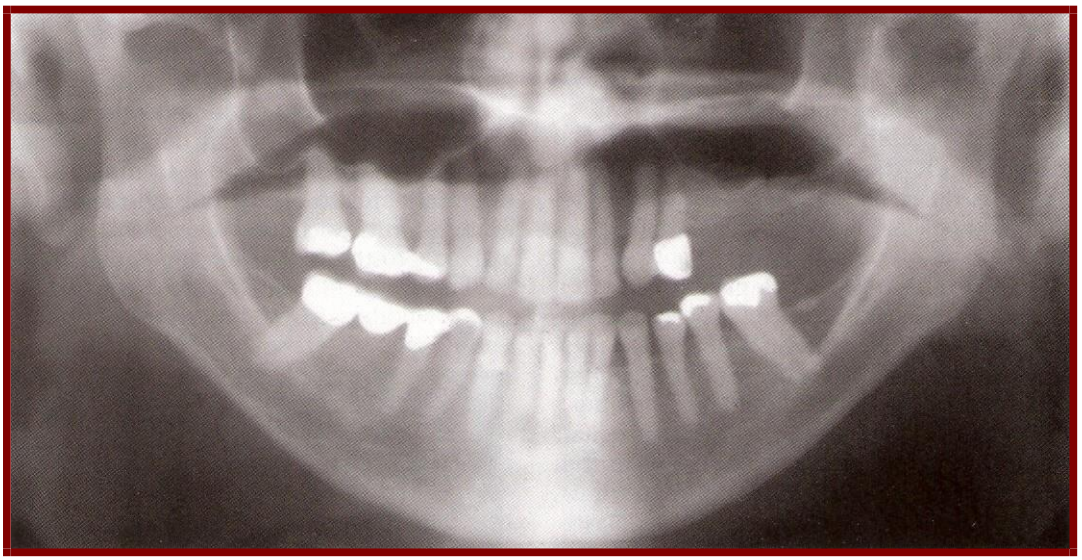


Figure 31: A preoperative radiograph showing division C-h bone in the maxillary premolar region with Division D in the molar region

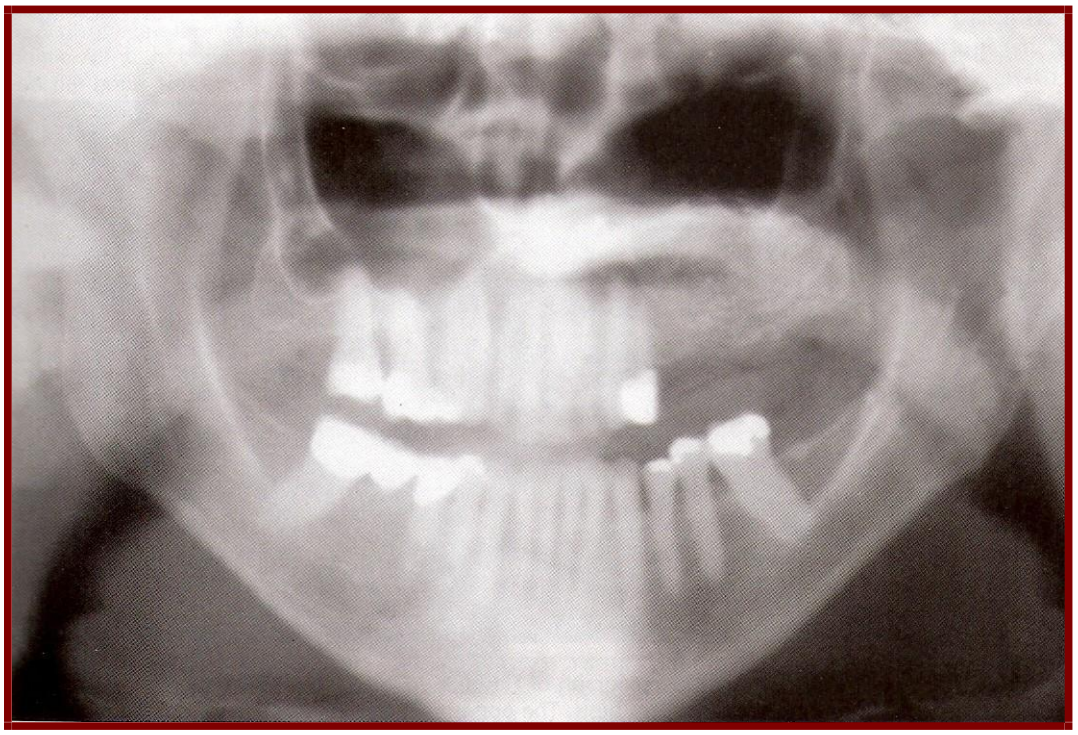


Figure 32: The posterior maxilla has been modified to Division A bone by sinus grafting.

2) Root-form implants

Additional implants are required to increase the overall implant-bone surface area to counteract the unfavorable force multiplier of increases crown height. For the same reason, in edentulous patients, an RP-5 prosthesis may be considered to reduce the cantilever.

Shorter textured implants may be suitable options in the posterior maxilla and mandible with compromised bone height as indicated by recent studies. [23, 38]

3) Other implant systems

- Subperiosteal
- Disk design
- Ramus frame
- Transosteal

C) Division C – a

1) Augmentation to improve the angulation

2) Subperiosteal implants

Division D (Deficient Bone)

Severe atrophy is used to describe the clinical condition (Fig 33).

Table 8: Division D dimensions

Basal bone loss • Flat maxilla • Pencil thin mandible > 20 mm crown height

Figure 33: The residual ridge on the right is a Division D with a dehiscent mandibular canal.

The completely edentulous Division D patient is the most difficult to treat. The surgical skill required is greater and the prosthetic outcome has a guarded prognosis. Fixed restorations are almost always contraindicated due to significant crown height. Idiopathic fractures during surgery or from implant failure or removal are likely complications (Fig 34).

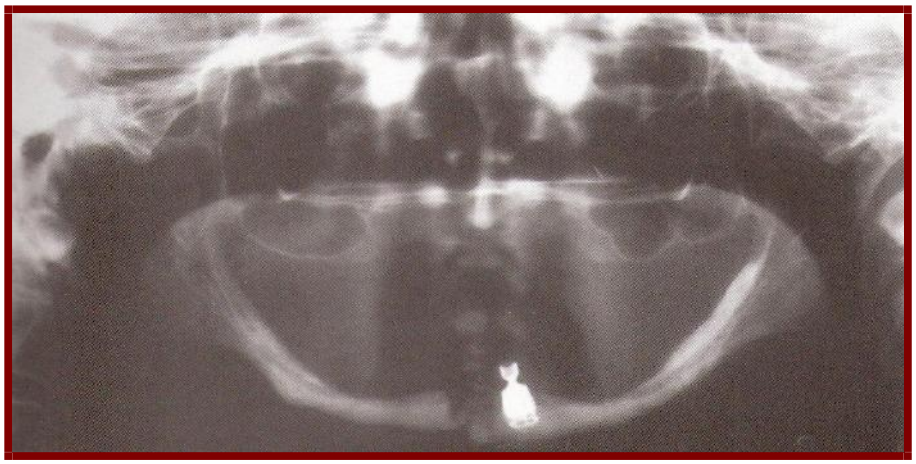


Figure 34: Implant failure has resulted in mandible midline fracture. Division D bone is the most difficult to treat.

Treatment Options for Division D Bone

Augmentation

- Autogenous bone grafts are indicated to upgrade the division.
- Endosteal or subperiosteal implants may be inserted depending on the division of bone attained.

Bone Density: Influence on Treatment Planning

Besides its external architecture, bone also has an internal architecture represented by i ts density. The strength of the bone supporting the endosteal implant is directly related to its density. Therefore, bone density exerts a significant influence on the clinical success of implant therapy.

A range of implant survival has been found relative to location. The anterior mandible has greater bone density than the anterior maxilla (Fig 35). The posterior mandible has poorer bone density than the anterior mandible. The poorest bone density exists in the posterior maxilla and is associated with dramatic failure rates (Fig 36).

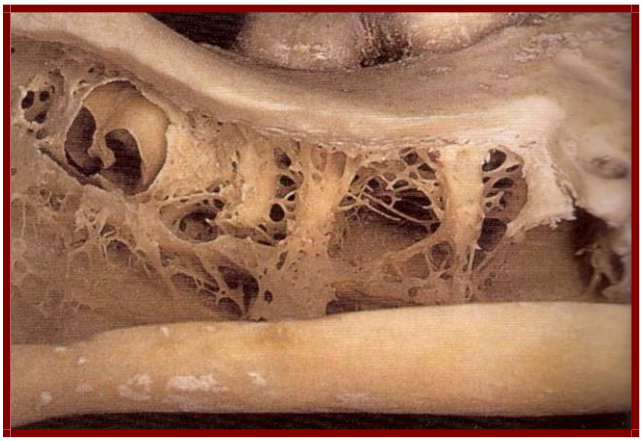


Figure 35: The dentate mandible has a coarser trabecular structure due to its force absorbing function

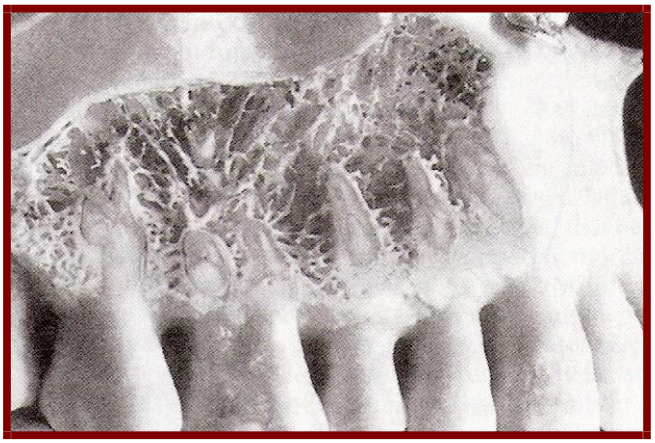


Figure 36: The dentate maxilla has a finer trabecular structure due to its force distribution function.

Specifically, it is the bone density (quality) encountered in these regions that influences implant success or fa ilure. A higher failure rate has been observed in poor quality bone compared with higher quality bone, irrespective of the location. [21]

Etiology of Variable Bone Density

Bone is a highly sensitive organ capable of responding to a number of factors, including hormones, vitamins, and mechanical influences.

In 1892, Wolff stated that: “Every change in the form and function of bone or of its function alone is followed by certain definite changes in the internal architecture, and equally definite alteration in i ts external conformation, in accordance with mathematical laws.”

Cortical and trabecular bone throughout the body are modified constantly by the processes of modeling and remodeling.

- **Modeling** has independent sites of formation and resorption and results in the change of the shape or size of bone. It is mainly observed during early bone growth and during healing.

- **Remodeling** is a process of resorption and formation at the same site that replaces previously existing bone and primarily is responsible for the maintenance or homeostasis of bone (internal turnover).

Both these adaptive phenomena are controlled primarily by the mechanical stress and strain environment within the host bone. Overall, the density of alveolar bone evolves as a result of mechanical deformation from microstrain. For example, alveolar bone is most dense around the teeth (cribriform plate) and denser around the teeth at the crestal region compared with the regions around the apexes (Fig 37).

Figure 37: Bone is most dense around the cribriform plate and at the crest due to functional requirements.

A decrease in the mechanical strain environment over a period of time will lead to a reduction in the bone density, e. g., around a tooth with no opposing occlusion or in regions of the maxilla or mandible after tooth loss.

According to Frost's Mechanostat Theory, four zones of bone can exist based on the mechanical adaptation to strain (Fig 38):

1) Acute Disuse Window (0 to 50 microstrains)

The microstrains exerted are the least in this zone. As a result, remodeling of bone is stimulated with greater resorption than formation taking place. The bone loses mineral density and disuse atrophy is seen to occur with a gradual net loss of bone.

2) Adapted Window (50 to 1500 microstrains)

This is an ideal physiologic loading zone with equilibrium between the resorptive and formative phases of remodeling taking place. This is the range of strain ideally desired around an endosteal implant.

3) Mild Overload Zone (1500 to 3000 microstrains)

Due to the overload, microfractures occur in the bone. Bone modeling is then stimulated during the healing phase. However, the new bone formed is immature woven bone which is weaker. As a result, the bone strength and density eventually may decrease the intensity of load increases.

4) Pathologic Overload Zone (greater than 3000 microstrains)

The microstrains exceed the adaptive capacity of bone and remodeling with greater resorption of bone occurs. If modeling does occur, then woven bone is formed because sustained repair is necessary. The crestal bone loss observed during early implant loading is due to pathologic overload.

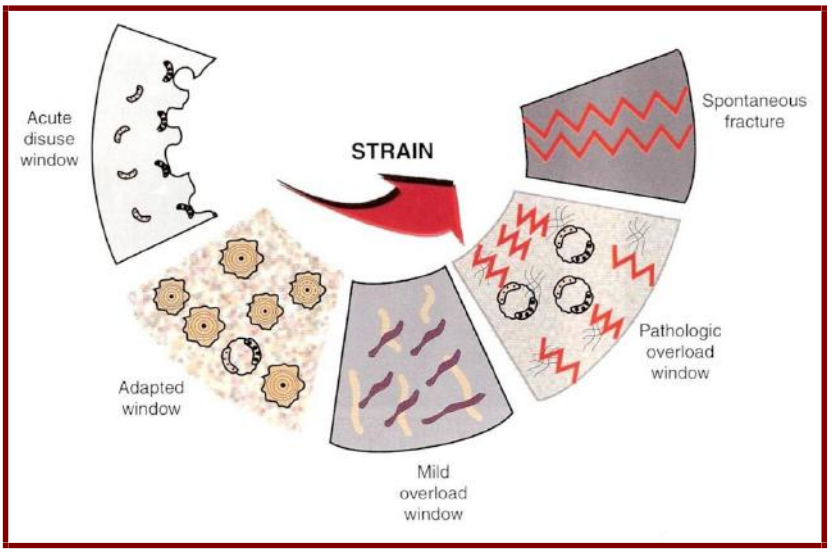


Figure 38: Frost's Mechanostat model depicting the four zones of microstrains

Lekholm and Zarb Bone Density Classification

In 1985, Lekholm and Zarb listed four bone qualities found in the anterior regions of the jawbone (Fig 39). Irrespective of the different bone qualities, all bone was treated with the same implant design and standard surgical and prosthetic protocol. Different survival rates were accordingly reported.

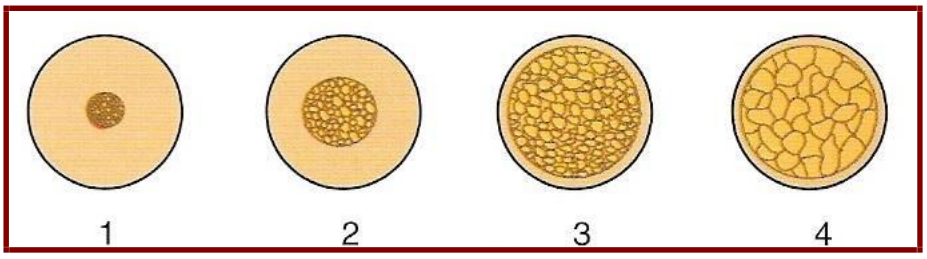


Figure 39: Lekholm and Zarb listed four bone qualities for the anterior regions of the jaws.

Table 9: Lekholm and Zarb Bone Density Classification

Bone Density	Description
Quality 1	Homogenous compact bone
Quality 2	Thick layer of compact bone surrounding a core of dense trabecular bone
Quality 3	Thin layer of cortical bone surrounding dense trabecular bone of favorable strength
Quality 4	Thin layer of cortical bone surrounding a core of low density trabecular bone

In 1988, Misch reported four bone density groups independent of the regions of the jaws based on macroscopic cortical and trabecular bone characteristics. Suggested implant design, surgical protocol, healing and progressive loading time spans have been described for each bone density type. Following this regimen, similar implant survival rates are observed for all bone densities.

Misch Bone Density Classification

Cortical bone found on the outer surfaces of bone includ ing the crest of an edentulous ridge may be either dense or porous. Similarly, trabecular bone found within the outer shell of cortical bone and occasionally on the crestal surface of an edentulous ridge may be either coarse or fine. These four macroscopic differences of bone are the basis of the classification system (Fig 40):

Table 10: Misch Bone Density Classification

Density	Description
D1	Dense cortical bone
D2	Thick porous cortical bone on the crest and coarse trabecular bone within
D3	Thin porous cortical bone on the crest and fine trabecular bone within
D4	Almost no crestal cortical bone. Fine trabecular bone composes all of the total volume of bone next to the implant

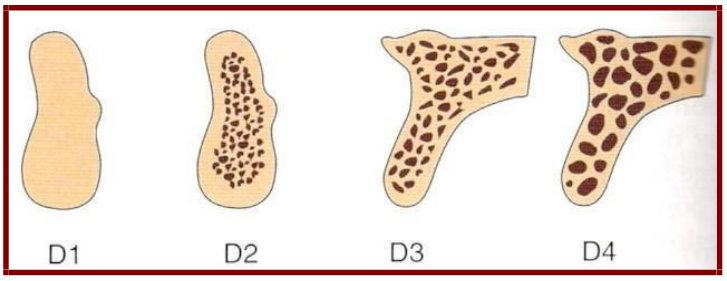


Figure 40: Misch's bone density classification is applicable to any region of the jaw.

Table 11:Usual Anatomical Location of Bone Density types (% occurrence)

Bone	Anterior Maxilla	Posterior Maxilla	Anterior Mandible	Posterior Mandible
D1	0	0	6	3
D2	25	10	66	50
D3	65	50	25	46
D4	10	40	3	1

For treatment planning purposes, generalizations regarding the bone density can be made based on the location. To err on the side of treatment planning for less dense bone is safer so that the prosthesis will be designed with slightly more, rather than less, support. Therefore:

- Anterior mandible is usually treated as D2 bone (Fig 41)
- Posterior mandible as D3 bone (Fig 42)
- Anterior maxilla as D3 bone
- Posterior maxilla as D4 bone (Fig 43)

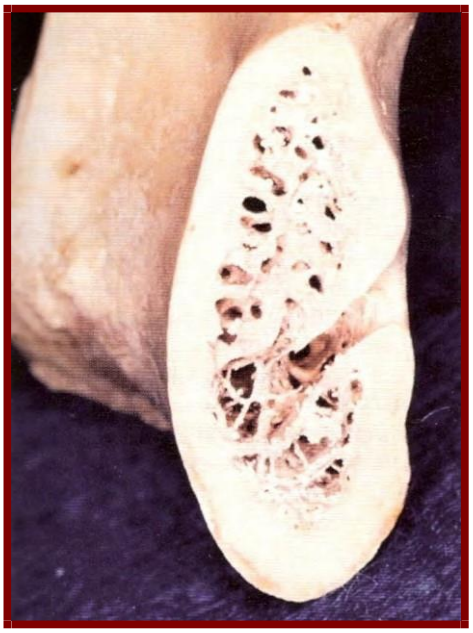


Figure 41: A cross-section of a D2 mandible in the region of the mental foramen.

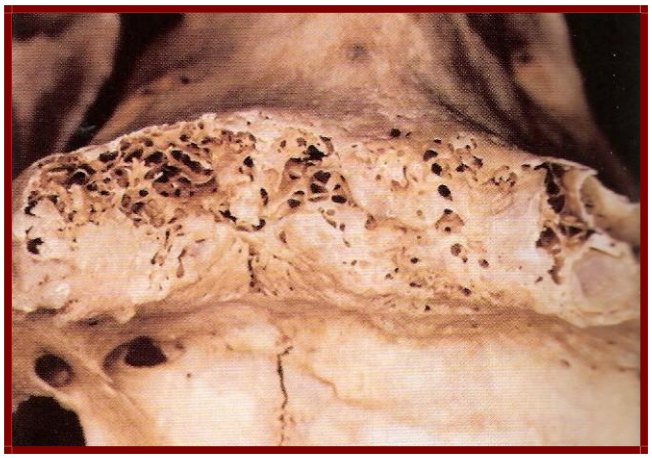


Figure 42: A posterior maxilla demonstrating D3 bone

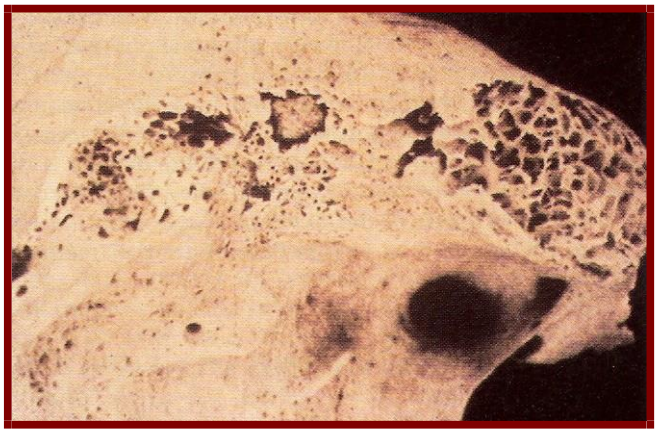


Figure 43: Poorest bone density is observed in D4 bone

Radiographic Bone Density

Periapical or panoramic radiographs are not accurate means to determine bone density because the lateral cortical plates often obscure the trabecular bone density. In addition, the more subtle changes of D2 to D3 cannot be quantified by these radiographs. A more precise method is through the use of Compute d Tomography. In general, the higher the CT number (Hounsfield unit), the denser the tissue.

Table 12: Computed Tomography Determination of Bone Density

Density	Hounsfield Units
D1	> 1250
D2	850 – 1250
D3	350 – 850
D4	150 – 350

Influence of Bone Density on Load Transfer

The initial bone density after implant placement is responsible for the mechanical immobilization of the implant during healing and distribution and transmission of stresses from the prosthesis to the implant-bone interface after healing.[21] The percentage of bone contact is significantly greater in cortical bone than in trabecular bone. The bone density influences the amount of bone-implant contact not only at first stage surgery but also at the second stage of uncovery and early prosthetic loading.

Hence, a greater implant surface area is required to obtain a similar amount of bone-implant contact in softer bone compared with denser bone.

Crestal bone loss and early implant failure after loading are mainly due to excess stress at the implant-bone interface. Based on finite element stress analysis studies carried out on different bone densities, a range of bone loss has been observed with similar loads on the implant:

- **D1 bone** – most stress concentration occurs around the crestal region of the implant and the stress is of lesser magnitude. Clinically, crestal bone loss is not observed (physiologic bone loads).
- **D2 and D3 bone** – slightly greater crestal stress concentration occurs and the intensity of the stress extends farther apically, along the implant body. Clinically, crestal bone loss is observed (pathologic overload).

- **D4 bone** – greatest crestal stress concentration occurs and the intensity of the stress extends farthest apically, along the implant body. Clinically, implant failure is observed (severe pathologic overloads).

Thus, it is important to modify the treatment plan according to the bone density encountered in the potential implant site.

Treatment Planning

As the bone density decreases, the biomechanical loads on the implants must be reduced. This can be accomplished in several ways:

1) Prosthesis design

- Angle of load on the implant body should be more axial and offset loads minimized.
- Narrower occlusal tables should be designed. [20]
- Splinting the crowns of adjacent implants with relatively stiff restorative materials may be considered. [17]
- Cantilever length may be shortened or eliminated in case of full-arch restorations for edentulous patients.
- RP-4 rather than FP prosthesis may be considered in edentulous patients to reduce nocturnal parafunctional forces.
- RP-5 prosthesis may be considered to permit the soft tissue to share the occlusal force.
- Night guards and acrylic occlusal surfaces distribute and dissipate the parafunctional forces on an implant system.

2) Implant Number

Increasing implant number is indicated in softer bone regions. This is an excellent way to reduce stress by increasing the functional loading area.

3) Implant Height

Increasing the implant height in softer bone results in be tter initial fixation and healing. [21] However, once initial healing is complete, the implant width is a more critical factor to reduce pathologic overload at the crestal region. [24]

4) Implant width

Wider diameter implants may be considered for D4 bone quality. [13]

5) Implant Design

A different implant design is strongly suggested for each bone density because bone has a tenfold difference in strength and flexibility between D1 and D4 bone qualities. The deeper the thread, the more functional the surface area. A D4 implant body should have more and deeper threads than a D1 implant body (Fig 44).

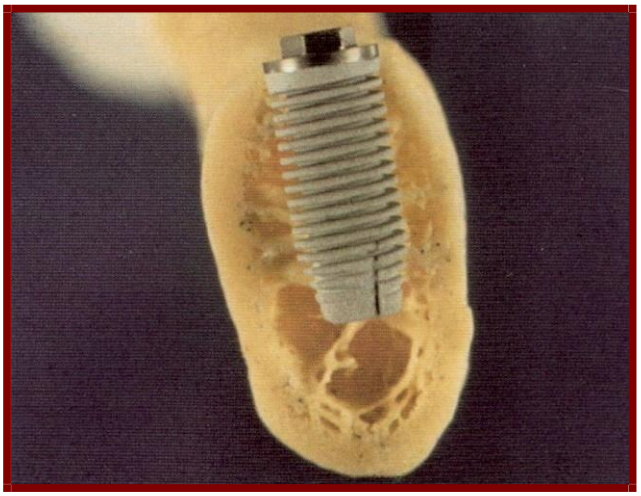


Figure 44: D4 bone requires increased surface area for bone-implant contact. Increasing the thread no. is one such method.

6) Implant Surface Condition

Coatings on an implant body increase the surface area for bone-implant contact.

7) Progressive Bone Loading

This provides for a gradual increase in occlusal loads, separated by a time interval to allow the bone to accommodate to the stress environment. Over time, progressive loading increases the density of bone at the implant interface and improves the overall support system mechanism. The softer the bone, the more important the progressive loading. Also, extended healing periods of 8 to 10 months are recommended. [13]

Stress Factors: Influence on Treatment Planning

Excess stresses to an implant interface may cause overload and implant failure (Fig 45). This may occur soon after surgery and result in implant mobility. In addition, the excess overload may be applied to a final restoration after successful implant integration and still result in implant failure. The most common complications in an implant reconstruction are related to occlusal overload and stress-related factors.

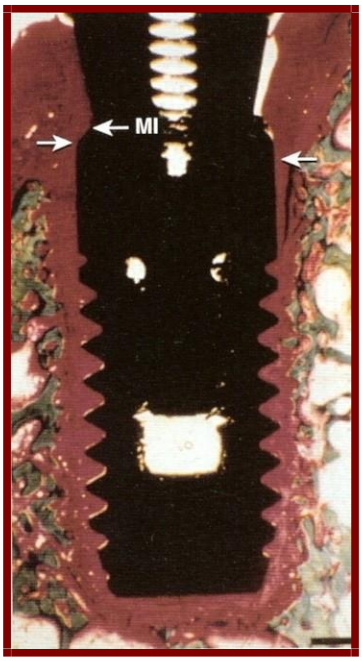


Figure 45: Micromotion has caused fibrous tissue integration due to overload.

Implant Complications from Stress

- Early crestal bone loss
- Occlusal overload bone loss
- Implant fracture (body or component)
- Screw loosening (prosthesis or abutment)
- Prosthesis fracture (occlusal material or framework)
- Implant failure

Early Crestal Bone Loss

The clinical success and longevity of endosteal dental implants is controlled in a large part by the health of the surrounding crestal region of bone and soft tissue. Early crestal bone loss has been observed around the permucosal portion of dental implants irrespective of the surgical approach and implant dimensions and can range from loss of marginal bone to complete failure of the implant. [31] The initial bone loss follows a V- or a U-shaped pattern described as *ditching or saucerization* . The amount of bone loss should be measured radiographically from the original level of crestal bone at insertion rather than from the first thread of the implant (Fig 46).

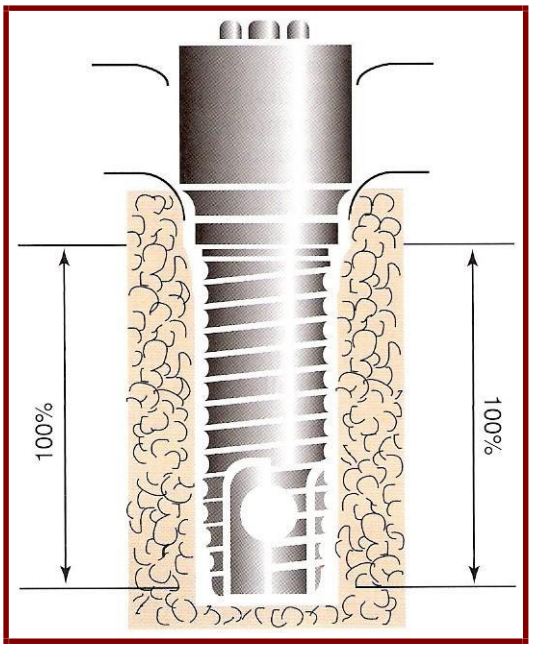


Figure 46: Marginal bone loss should be measured from the original crest of bone and not from the first thread.

Greater magnitude and occurrence of bone loss during the first year of prosthesis loading is observed. The amount of crestal bone loss observed varies and dramatically decreases after the first year. This observation is so frequent that proposed criteria for successful implants often do not even include the first year bone loss amount.

Instead, recommended criteria for implant success include less than 0.2 mm of bone loss annually after the first year of service. [1] This has been questioned by Bryant who states that young implant patients could then be projected to lose up to 8 mm of bone

over the ensuing 40 years. [22] In any case, crestal bone loss around dental implants has not been found to differ with age and both older and young adults should anticipate many years of implant function in the context of bone behaviour patterns.

A correlation has been observed between increased crestal bone loss and implant location. Marginal bone loss observed in the maxilla is slightly greater than that in the mandible. [4,31] This may be due to the differences in the remodeling capacity and rate between maxillary and mandibular bone. Maxillary bone provides important vascularization and a greater remodeling potential in the healing phase after implant placement. In contrast, the reaction of the mandible is slower and more time is required to lose the same amount of bone around the implant. Crestal bone loss has also been associated with smoking habits. [4,31]

Early crestal bone loss around an implant is rarely associated with a corresponding shrinkage of the surrounding soft tissue. Thus, peri- implant suprabony and infrabony pockets are established as bone loss progresses. Anaerobic bacteria are predominant in pockets greater than 5 mm deep and are associated with further bone loss and decrease in periimplant health. Moreover, once a soft tissue pocket is greater than 4 mm deep, daily oral hygie ne measures become compromised and further aggravate the condition. Thus, it

is desirable to reduce the early crestal bone loss to maintain a favorable local environment for the periimplant health.

Stress Factor Hypothesis for Early Crestal Bone Loss

The microscopic organization of bone changes during the first year after implant placement. Initially, woven bone which is weaker and unorganized is formed around the implant. Lamellar bone which is a load-bearing structure is formed several months after the woven bone has replaced the devitalized zon e around the implant at insertion.

Bone is 60% mineralized at 4 months and takes 52 weeks to completely mineralize. Hence, at second stage surgery when the implant is uncovered and the prosthesis is loaded, the bone is less dense and weaker (as compared to after 1 year of prosthetic loading). A precaution to be taken at this time is to avoid trauma to the crestal region of bone since the healing response may again require additional time to develop a mature bone interface.

As functional forces are placed on the implant over a period of time, the bone is able to respond to the stresses and improve its density and strength. Thus, during the first year, due to the nature of the bone (less dense), the crestal zone of the implant may be in the pathologic overload zone because the stresses are highest at the

crest. Hence, early crestal bone loss occurs. However, the strain of lesser magnitude applied below the crest still may be in the physiologic zone, allowing the bone to remodel and to become dense and stronger.

As a result, the occlusal overload that caused bone loss initially is not great enough to cause continued bone loss once it becomes denser. The bone loss may then stop because the bone has become stronger.

The modulus of elasticity (stiffness) of titanium is more than 5 to 10 times more rigid than cortical bone. A mechanical principle states that when two materials of different moduli are placed together with no intervening material and one is loaded, a stress contour increase will be observed where the two materials first come into contact. This phenomenon can be observed in photoelastic and three-dimensional finite element analysis studies (Figs 47 and 48). The stresses form a V- or U- shaped patter similar to that observed clinically. The values are greatest at the crest and gradually decrease in density as the stress is dissipated throughout the implant length. The apical end of the implant receives no appreciable stress.

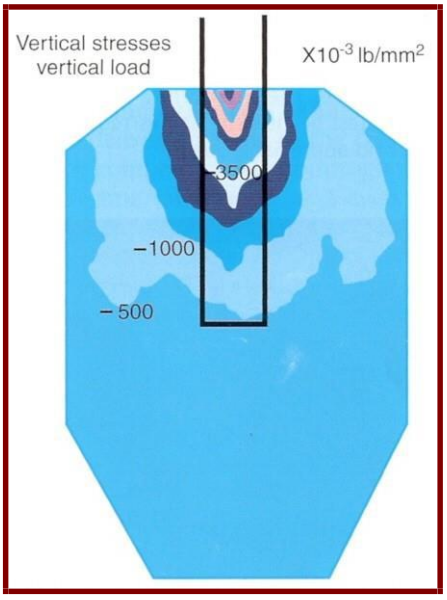


Figure 47: V-shaped stress patterns are visible on finite analysis.

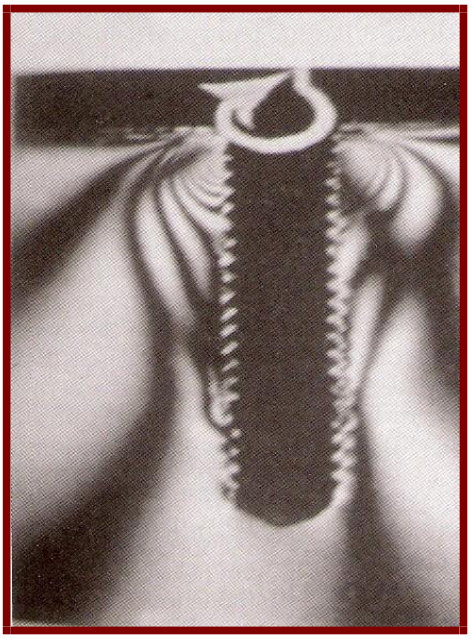


Figure 48: Photoelastic pictures reveal similar patterns. The apex of the implant does not receive appreciable stress.

Thus, the stress factor hypothesis explains why early crestal bone loss occurs during the first year with a significant decre ase thereafter.

Effect on Treatment Planning

Stress is therefore a very important factor to be considered before treatment. Treatment plans should incorporate methods to reduce stress and minimize its initial and long -term complications. The following factors should be taken into consideration to improve the environment of the transosteal region in order to manage stress around and within endosteal implants:

- Bone density
- Abutment number
- Abutment position
- Implant size
- Implant design
- Progressive loading

1) Bone Density

The denser the bone, the less crestal bone loss observed. [21] D1 bone is about 10 times stronger than D4 bone and D2 bone is about 50% stronger than D3 bone. The depth and geometry of the V-shaped pattern of stress around the implant vary in different bone

densities. A very dense bone captures the stress closer to the crestal region. A very soft bone allows the stress to be transmitted along the implant interface.

Bone density also affects the stiffness of the bone. Young' s modulus for compact bone is 10 times larger than for cancellous bone. The denser the bone, the more stiff it is, and the less biomechanical mismatch to titanium during loading. This may result in *"stress shielding"* of the bone and induce disuse atrophy. Thus, as the bone density decreases, the biomechanical loads on the implants must be reduced. This can be accomplished through means described previously.

2) Abutment Number

The overall stress to the implant system may be reduced by increasing the area over which the force is applied. Increasing the number of implants supporting the prosthesis is the most effective way to achieve this (Fig 49).

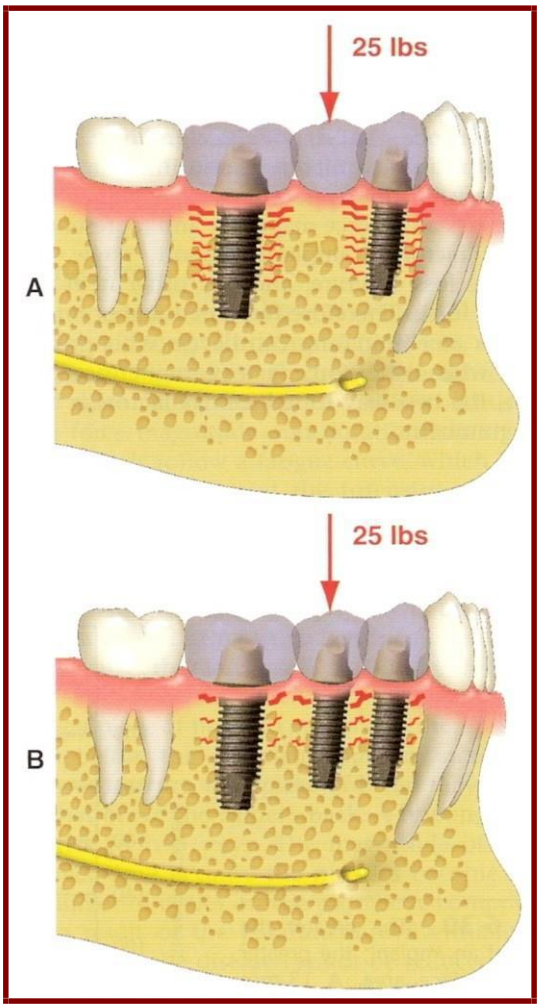


Figure 49: Increasing the implant number reduces the force applied to each component.

3) Abutment Position

Implant positioning is also related to implant number because more than two implants are needed to form a biomechanical tri pod which is more resistant to loading. Cantilevers are a force magnifier and represent a considerable risk factor. Therefore, implant number

and position should aim at eliminating cantilevers whenever possible especially when other force factors are increased (Fig 50)

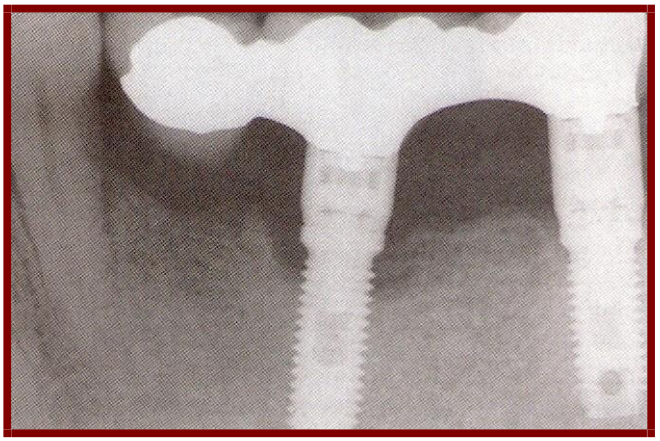


Figure 50: Crestal bone loss is more evident on an implant supporting a cantilever

4) Implant Size

Increasing the implant width is an effective way to reduce crestal stresses. [24] Bone augmentations in width may be indicated to increase implant diameter by 1 - mm when force factors are greater than ideal.

A study conducted emphasizes the need to enhance the facial plate thickness especially in the maxilla (a poor load - bearing structure) in order to optimize stress dissipation. This added consideration has been recommended while selecting implant diameter. [12]

By and large, wider diameter implants are recommended in posterior edentulous areas where bone height is limited. Besides increasing the surface area for bone-implant contact, stress dissipation is also enhanced since the implant captures the stress at its crest. [10,24,34]

It is important to note that most implant designs only increase 25% to 50% in surface area from the smallest to the largest size. In comparison, there is a 300% surface area increase from the lower anterior teeth to the maxillary molars. Thus, increasing implant number is most beneficial to decrease stress when conditions warrant with supplemental implant support gained from an increase in implant diameter.

5) Implant Design

Implant macrodesign may affect surface area even more than an increase in width. A smooth cylinder implant provides 30% less surface area than a threaded implant of the same size. Increase in the number as well as the depth of the threads results in a greater surface area (Fig 51).

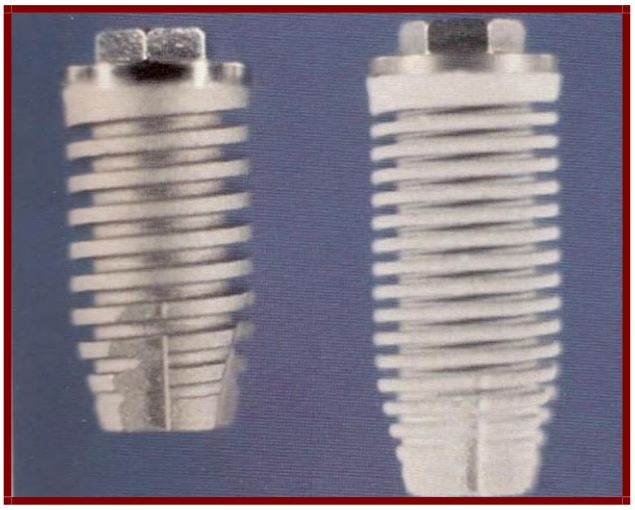


Figure 51: Increasing thread no. increases the surface area of contact.

Early crestal bone loss during the first year of loading often corresponds with the length of the polished collar and is observed to stop at the first thread (Fig 52).

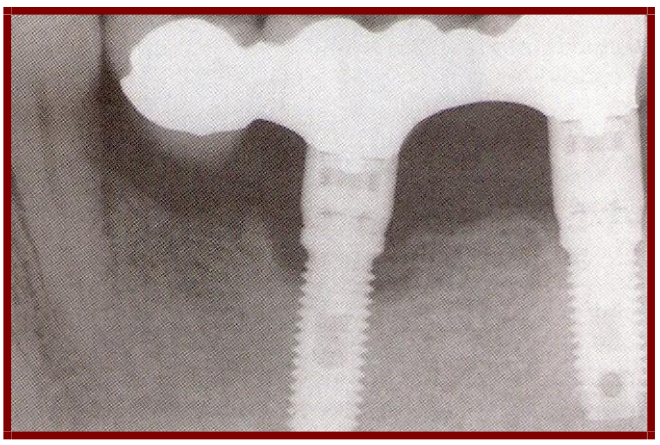


Figure 52: The early crestal bone loss during the first year often stops at the first thread (or roughened area) and corresponds to the smooth collar.

A smooth collar transmits shear forces to the bone. Bone is strongest to compressive forces, 30% weaker to tensile loads, and 65% weaker to shear forces. Hence, bone grows to the smooth metal but when the implant is placed in function, this bone is more likely to resorb. The first thread corresponds to a change from shear to compressive or tensile loads. Thus, a 40% to 70% increase in bone resistance to loads may be able to halt the bone loss process.

6) Progressive Loading

Progressive loading influences the amount and density of the implant-bone contact. The bone is given time to respond to a gradual increase in occlusal load. This increases the quantity of bone at the implant interface, improves the bone density and improves the overall support mechanism.

Force Factors Related to Patient Conditions

Various patient conditions exert different amounts of force in terms of magnitude, duration, type, and direction. This influences the stress environment of the implant and prosthesis. The treatment plan may need to be modified depending on the force factors pertaining to the individual patient. These influencing factors are:

1) Parafunction
2) Crown height
3) Position of the abutment in the arch
4) Direction of load forces
5) Nature of the opposing arch

1) Parafunction

Parafunction is one of the most common causes of implant failure. Parafunctional forces are characterized by their repetitive nature and are considered to be harmful to the stomatognath ic system. Three main patient conditions are associated with parafunction:

- Bruxism
- Clenching
- Tongue thrust

Patients presenting with especially bruxism or clenching require careful diagnosis of the condition and modification of the treatment plan due to the excessive forces generated. Long term success is not always predictable but this should not deter us from treating these patients.

Bruxism

Bruxism is the most common oral habit observed and occurs due to the vertical or horizontal, nonfunctional grin ding of teeth (dynamic in nature). The etiology of bruxism is multifactorial.

The forces involved (upto 1000 lb) are in significant excess of normal physiologic masticatory loads in both duration and magnitude. These forces may occur while the patient is awake or asleep (nocturnal bruxism) and may generate several hours per day of increased force on the teeth. The maximum biting force is also greater than average due to the constant exercise of the muscles of mastication. *The characteristic clinical sign of bruxism is tooth wear* (Fig 53).

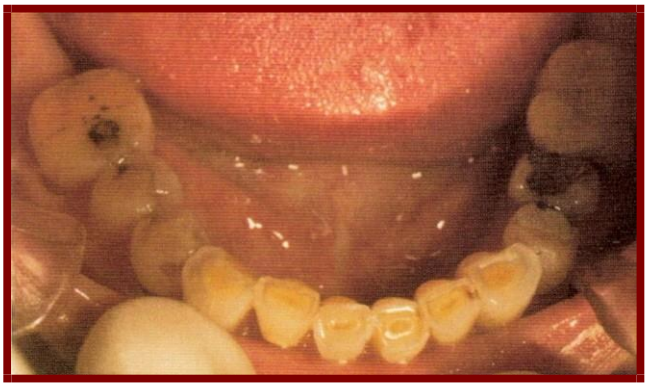


Figure 53: Severe bruxism with anterior and posterior wear

Clenching

Clenching is a parafunctional habit in which a constant force (static load) is exerted from one occlusal surface to the other without any lateral movement. A habitual clench position exists which may or may not coincide with centric occlusion.

Clenching is similar to bruxism in that the forces involved are in significant excess of normal physiologic loads in both duration and magnitude. The distinguishing feature is in the nature of the force exerted. In clenching, the forces generated are more vertical to the plane of occlusion and detrimental horizontal forces are minimal . *Thus, wearing of the teeth is not likely and serves to distinguish between bruxism and clenching.*

Certain common clinical signs and symptoms are observed in patients reporting with bruxism or clenching:

Common Symptoms

- Repeated headaches
- Jaw discomfort or muscle tenderness on awakening
- Tooth sensitivity to cold
- History of repeated uncemented and fractured restorations

Common Clinical Signs

- Hypertrophy of temporalis and masseter muscles due to constant overuse.
- Tenderness of the temperomandibular joint.
- Tenderness on palpation of temporalis, masseter, and lateral pterygoid muscles due to fatigue and incoordination.
- Deviation of the mandible on opening to one side indicative of muscular imbalance on the same side.
- Limited opening which indicates muscular imbalance or degenerative joint disease. The normal inter-incisal opening in an Angle's Class I patient should be at least 40 mm.
- Fracture of teeth or restorations and uncemented restorations (Fig 54).
- Cervical erosion or abfraction of teeth (Fig 55).

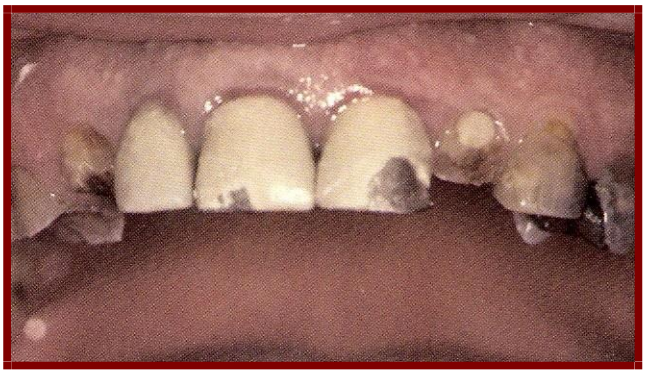


Figure 54: Repeated fractured restorations are a common finding in bruxism

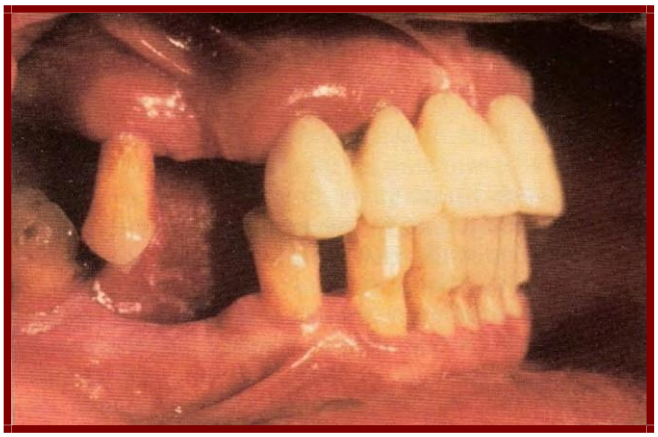


Figure 55: Cervical abfraction seen in clenching

Fatigue Fractures

Materials follow a fatigue curve which is related to the number of cycles and intensity of the force. A bruxing or clenching patient is at a higher risk in two ways. The magnitude of the force increases over time because the muscles become stronger, and the number of cycles increases on the prosthetic components.

Eventually, the tooth, the implant or the prosthesis wi ll break if the disorder cannot be reduced in intensity or duration (Figs 56 and 57). No long-term prosthetic result is expected in patients with severe bruxism.

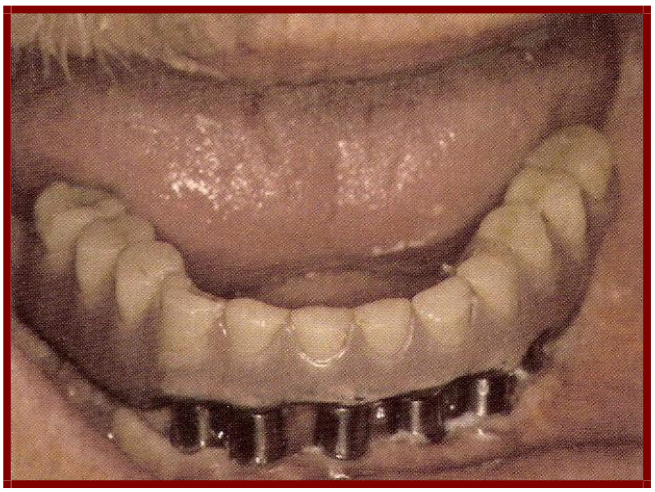


Figure 56: Severe bruxism is evident on this hybrid prosthesis

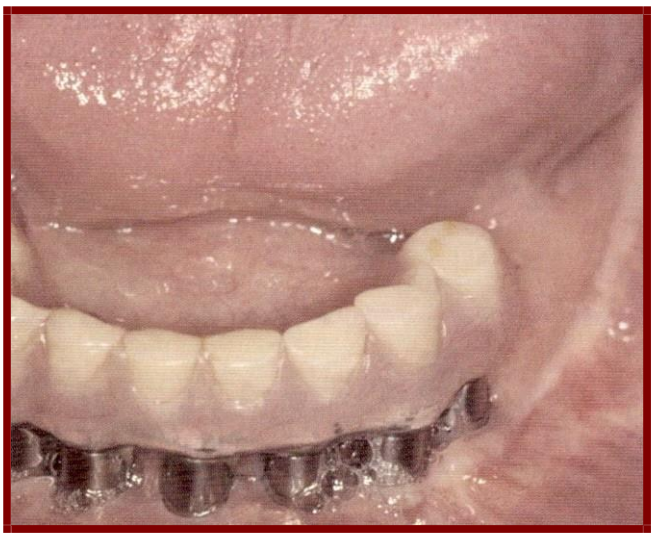


Figure 57: Fatigue failure has occurred due to sustained loading

Specific Clinical Signs in Clenching

- *Scalloped border of tongue* – The tongue is often braced against the lingual surfaces of the teeth during clenching, exerting lateral pressures and resulting in the scalloped border (Fig 58).

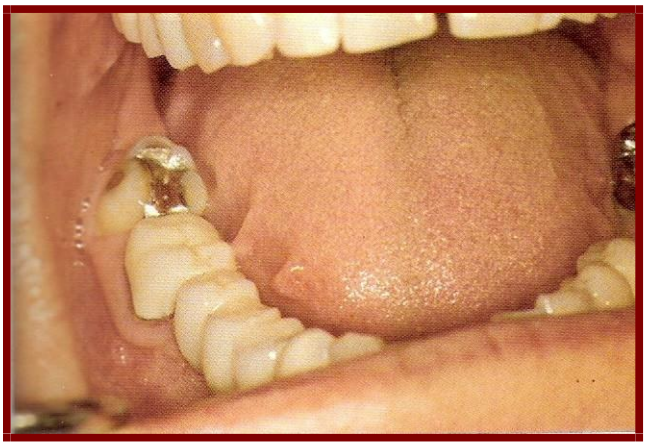


Figure 58: Scalloped border of tongue is often found in a clenching patient

- *Fremitus* – This is a vibration type of mobility often observed in the clenching patient . To evaluate this condition, the operator' s finger barely contacts the facial surface of one tooth at a time and feels for vibrations while the patient taps the teeth together. Fremitus is symptomatic of local excessive occlusal loads.

Specific Clinical Signs in Bruxism

The characteristic diagnostic sign of bruxism which differentiates it from clenching is the wearing of teeth or restorations. Nonfunctional wear facets on the occlusal surfaces of

posterior teeth; attrition of incisal edges of maxillary and mandibular canines; and notching of the cingulum of maxilla ry anterior teeth are confirmatory signs (Fig 59).

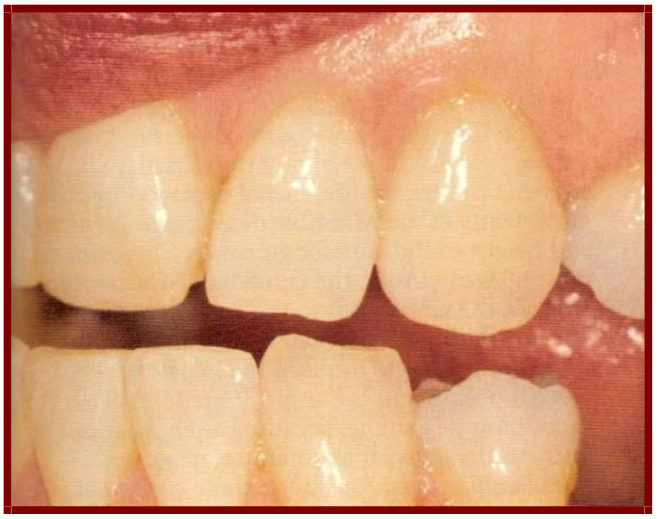


Figure 59: Wear facet on mandibular canine and slight notch in maxillary lateral incisor. The patient has mild bruxism.

Isolated anterior wear seen in mild bruxism is not much of a concern as long as the anterior incisal guidance is still functional during excursive movements. This is because the masseter and temporalis muscles contract when the posterior teeth contact and with incisal guidance (and an absence of posterior contact), two - thirds of these muscles turn off which dramatically reduces the bite force. For the same reason, posterior wear patterns associated with a loss of anterior guidance in excursions are more difficult to manage. The occlusal plane, the incisal guidance, or both may need modification to eliminate all posterior contacts during mandibular excursions before implant restoration.

Bruxers often have an *emgram* pattern of mandibular movement in one particular direction. This may result in a specific wear pattern primarily on one s ide of the arch (Fig 60). This *'emgram pattern'* or '*pathway of destruction'* usually remains after treatment. Implants placed and restored along such emgram pattern pathways are more prone to complications arising due to the greater stresses applied.

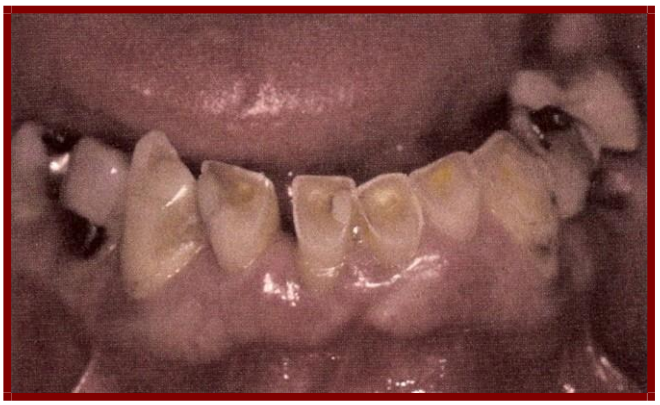


Figure 60: Emgram pattern of bruxism toward the left canine to central incisors. This "pathway of destruction" is specific.

Recently, polysomnographic study analysis has been evaluated to be an effective and low-cost method to confirm occlusal parafunctional habits during sleep. [19] This may be an adjunctive aid to the clinician in diagnosing bruxism.

Treatment Considerations

1) Elimination of premature contacts

An occlusal analysis should be carried out to i dentify any premature contacts during mandibular excursions. An elimination of eccentric contacts may allow recovery of the periodontal ligament health and muscle activity within 1 to 4 weeks.

2) Night Guard

A night guard should then be given with even occlusal contacts around the arch in centric occlusion and posterior disocclusion with anterior guidance in all excursive movements. The patient is advised to wear the device for a period of 4 weeks at night.

The night guard is then refabricated with 0. 5 to 1 mm of colored acrylic resin on the occlusal surface. If the patient wears this device for a further 4 weeks, the influence of occlusion on the bruxism may be observed directly. Because no contacts are premature while the device is worn, if the colored acrylic is still intact, the nocturnal parafunction has been reduced or eliminated. Therefore, further occlusal reconstruction or modification is warranted. However, if the colored acrylic on the night guard is ground through, an occlusal adjustment will have little influence on decreasing the habit.

Unlike teeth, implants do not extrude in the absence of occlusal contacts. As a result, in partially edentulous patients, the night guard can be relieved around the implant crowns, so the remaining natural teeth bear the entire load. For example, for a maxillary implant restoration, the maxillary night guard is hollowed out so that no occlusal force is transmitted to the implant crown(s) (Fig 61). When the restoration is in the mandible, the occluding surfaces of the maxillary night guard are relieved over the implant crowns.

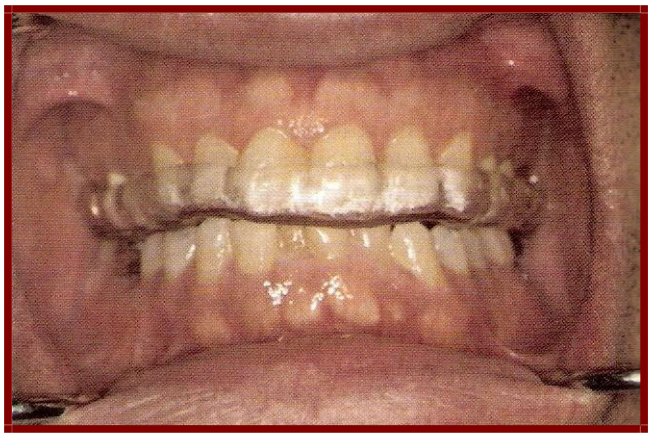


Figure 61: Maxillary implant crown should be completely relieved from the guard.

Similarly, a mandibular posterior cantilever on a full-arch implant prosthesis also may be taken out of occlusion with a maxillary night guard. When a posterior quadrant of implants supports a fixed prosthesis in the maxilla, a soft reline material may

be placed around the implant crowns to act as a stress relief element and decrease the impact forces on the restoration (Fig 62). When full- arch implant restorations are opposing each other, the night guard should provide solely anterior contacts during centric occlusion and mandibular excursions.

Figure 62: A soft reline material should be placed around an implant when the prosthesis is in the posterior region.

3) Implant considerations in the posterior region

- Additional implants, increased implant dimensions are often necessary in the bruxing patient.
- Occlusal considerations – The anterior teeth may be modified to recreate the proper incisal guidance to avoid posterior interferences during excursions.

4) Implant considerations in the anterior region

- Additional implants preferably of greater diameter are indicated.
- In the presence of natural, healthy canines, a canine guided occlusion is the occlusal scheme of choice.
- If the canine is absent and is restored, then a mutually protected occlusion is indicated.

5) Clenching

Alteration of the anterior occlusal scheme is not as critical due to absence of detrimental horizontal forces . A soft night guard with a hard acrylic outer shell and inner soft resilient liner, with slight relief over the implants, is often beneficial in reducing the impact of the forces during parafunction.

6) Care during healing phase

A common cause of implant failure during healing is parafunction in a patient wearing a soft tissue- supported prosthesis over a submerged implant. The tissue overlying the implant is compressed during parafunction and the premature loading may cause micromotion and compromised osseointegration. The prosthesis over the implant should be relieved generously during the healing period whenever parafunction is noted.

7) Progressive bone loading

This provides additional time to produce load bearing bone around the implants.

8) Additional Occlusal considerations

- Centric vertical contacts aligned with the long axis of the implant whenever possible.
- Narrow posterior occlusal tables prevent inadvertent lateral forces; decrease the forces necessary for mastication; and leave greater space for the tongue. [20] Adjacent implant crowns may be splinted together. [17]
- Enameloplasty of the cusp tips of the opposing natural teeth is indicated to help improve the direction of vertical forces, within the guidelines of the intended occlusion.

9) Completely edentulous patients

If anatomical conditions do not permit the placement of additional implants in the presence of parafunction, a removable overdenture (RP -4 or RP- 5) should be considered. The prosthesis may be removed during periods conducive to noxious habits.

Tongue Thrust and Size

Parafunctional tongue thrust is the unnatural force of the tongue exerted against the teeth during swallowing. Although of lesser intensity, the force exerted is horizontal and can increase stresses at the permucosal site of the implant (Figs 63 and 64).

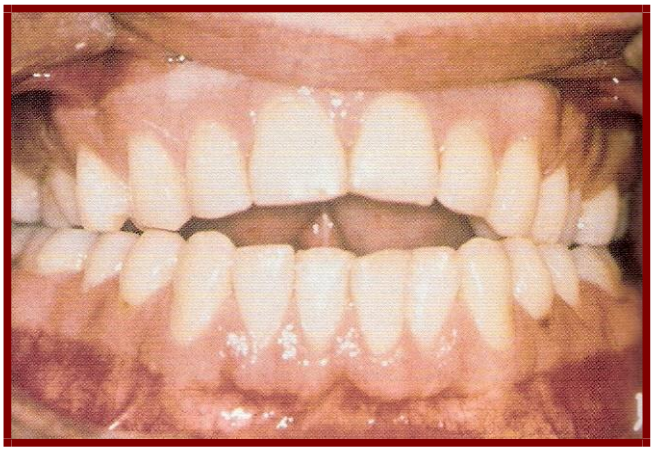


Figure 63: Anterior tongue thrust habit

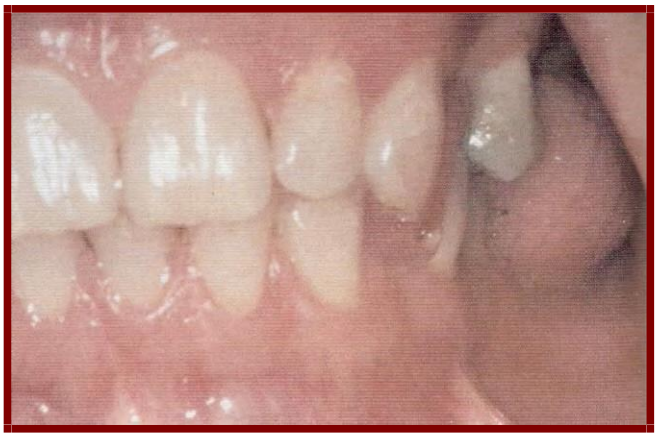


Figure 64: Posterior tongue thrust due to the loss of posterior teeth.

Tongue thrust may lead to tooth movement or mobili ty which results in additional loads on implants in the same quadrant. If the natural teeth were lost as a result of an aberrant tongue position or movement, the prognosis of implants at the site is compromised due to an increased risk during initial healing and early prosthetic loading. The excess force exerted is even more critical in one -stage surgical approaches because the implant is in an elevated position at initial placement and the implant interface is in an early healing phase.

The tongue may also enlarge with the loss of teeth to accommodate to the available space. This is often seen in patients with edentulous lower ridges. The increased lateral force exerted due to the enlarged tongue may compromise the placement of implants and subsequent restorations. The patient may also complain of inadequate space for the tongue post -treatment and may bite it during function. However, the tongue usually accommodates to the new intra-oral condition. Submerged, two-phase protocols are recommended in patients with horizontal force factors due to the lateral tongue thrust.

2) Crown Height

For every 1 -mm increase in crown height, a force increase of 20% may occur. When the crown height/implant body ratio is unfavorable (>1), a greater number of implants or wider implants may be considered to counteract the increase in stress.

3) Position of the Implant in the Arch

The maximum biting force is generated in the molar region. The anterior natural tooth roots are smaller in diameter due to the lesser forces generated. The major increase in natural tooth surface area occurs in the molar region. Yet in implant dentistry, longer implants are placed in the anterior region and shorter implants in the posterior regions. This concept should be modified to follow a biomechanical rationale of treatment plannin g similar to that observed with natural teeth. Implants in the posterior regions should be of greater diameter, especially in the presence of additional force factors.

A recent study has concluded that when a missing mandibular molar is to be replaced with an implant-supported crown, one may consider the use of either a wider diameter implant or 2 regular diameter implants. [28] Another study has showed that in immediate extraction mandibular molar sites, wider diameter implants in conjunction with a resorbable membrane graft provide reasonable success rates.

4) Direction of Load

The direction of the occlusal load results in a significant difference in the amount of force exerted on an implant. Much less stress occurs with vertical loads compared to an angled load on an implant.

Lateral forces represent a 50% to 200% increase in compressive stress compared with vertical loading, and tensile stresses may increase more than tenfold. Moreover, the shear component of a force is not present with an axial load but is increased dramatically as the angle of the force increases.

Anatomical configurations of bone significantly affect the implant angulation and force direction. In the presence of labial concavities in the anterior region, implants are often placed with a palatal angulation of the implant apex. Care should be taken to preserve the facial cortical plate at the time of surgery due to the compromised loading situation present. [12]Mandibular molar implants may be placed with a lingual inclination of the implant body to avoid perforation of the submandibular fossa. Mandibular premolar implants are best positioned for axial loading.

If the forces of occlusion are not axial to the implant body, the treatment considerations should include additional implants, wider implants, stress relievers in the prosthesis, or overdentures

5) Opposing Arch

Natural teeth transmit greater impact forces through occlus al contacts than do soft tissue- borne complete dentures. Patients with partial dentures may record forces intermediate between those of natural teeth and complete dentures.

The highest force factors have been found with opposing implant prostheses. [18,29] A possible explanation provided is that an implant-supported fixed prosthesis does not benefit from proprioception provided by the periodontal ligament and therefore patients may bite with a force four times greater than with natural teeth. In addition, premature contacts in occlusion or parafunction do not alter the pathway of closure because of decreased occ lusal awareness (due to lack of proprioception).

Preimplant Prosthodontics

Preimplant prosthodontic considerations are a vital phase of treatment before implant surgery and should be carried out in a sequential manner. The following four factors have to initially be evaluated both during the clinical examination and on the diagnostic casts:

1) Maxillary anterior tooth position
2) Existing occlusal vertical dimension
3) Mandibular incisal edge position
4) Existing occlusal planes

1) Maxillary Anterior Teeth Position

The position of the maxillary anterior teeth is assessed using established esthetic and speech criteria. This position is important because it influences:

- Esthetics
- Occlusal vertical dimension
- Mandibular tooth position
- Posterior plane of occlusion

If the maxillary anterior teeth position is undesirable, it needs to be corrected before restoring any other region of the mouth.

2) Existing Occlusal Vertical Dimension

This is the next criterion to be assessed. The OVD is defined as the distance between two points (one in the maxilla and the other in the mandible) when the teeth are in occlusion. The OVD is not a constant dimension and often decreases over time.

Assessment of the OVD needs to be performed before implant placement, for it may influence several other aspects, such as esthetics, interarch space or anteroposterior (A -P) jaw relationship. Evaluation is accomplished by subjective (physiologic rest position, closest speaking space) as well as objective methods (facial measurements). No consensus exists on the ideal method to obtain the OVD. Yet its determination is critical enough because it significantly influences the final treatment plan.

In a completely dentate patient or one with posterior and anterior stops, the OVD is easily assessed as the existing dimension when the teeth are in contact. However, patients who have been partially or completely edentulous for several years may exhibit a collapsed OVD and the final restorative goal is less simplistic.

Alteration of OVD

Because the OVD is not an exact measurement, the ability to alter this dimension within limits nay be beneficial.

It should be determined whether there is a need to reestablish the OVD. This is an important decision needed to be taken when a full-mouth rehabilitation procedure is planned involving implants because almost all segments will require restorations. O rthodontic extrusion may be considered to reestablish the OVD when the teeth do not require restoration for any other reason.

The smaller the OVD, the more Class III the maxillo-mandibular jaw relationship becomes; and the greater the OVD, the more Class II the relation becomes. The OVD may be increased in order to make the mandible less harsh looking for a patient with a large chin button (mental prot uberance).

In addition, anterior mandibular implants on occasion are too facial to the natural incisal edge position, and increasing the OVD makes them much easier to restore. The OVD may be reduced in order to improve the direction of force on anterior implants.

Bruxism

This is commonly associated with a reduced OVD.

- If the OVD is acceptable in spite of the advanced wear of the teeth, crown lengthening and endodontic therapy may be required before reconstruction of the anterior teeth.

- If the OVD is closed, tooth preparation and the restoration of the OVD and incisal guidance is the treatment goal.

Sometimes, patients with a history of tooth abrasion or attrition do not exhibit a decrease in the OVD. Due to the slow loss of incisal enamel over time, the anterior teeth along with the alveolar process may erupt and maintain the OVD. The alveolar process merges toward the occlusal plane as the teeth become shorter and shorter in appearance. Posterior tooth wear is often not present due to intact incisal guidance. The following options may be considered in such situations:

- A surgical crown lengthening procedure can be done to correct the bone overgrowth followed by apical positioning of the soft tissue. The anterior teeth are then restored and canine guided occlusal schemes are established.

- If the extrusion is extreme or the size of the anterior roots are short, crown lengthening is contraindicated. The treatment plan may include extraction of the anterior teeth followed by osteoplasty to regain sufficient crown height space before implant placement.

Combination Syndrome

This clinical situation is usually observed in a patient wearing a maxillary complete denture opposing a Kennedy Class I partially edentulous region in the mandible and has recently been associated with a mandibular implant-supported full-arch or overdenture opposing a maxillary complete denture. [25] The clinical findings are:

- Maxillary anterior bone loss due to which the denture moves up and posteriorly.
- Highly mobile tissue in the premaxilla.
- Maxillary tissue hyperplasia on the palate.
- The maxillary tuberosities are enlarged and invade the mandibular edentulous area.
- The mandibular anterior teeth supraerupt beyond the maxillary incisal plane.
- A lack of posterior bone in the mandible due to a long period of edentulism.
- The horizontal occlusal plane is up in the anterior region and down in the posterior region which compromises esthetics due to visibility of posterior teeth.

The existing OVD is a critical element in these patients because of the incidence of a mandibular incisor extrusion beyond the maxillary anterior incisal plane (Fig 65). Not only are the teeth

extruded but also the alveolar process usually accompanies these teeth.

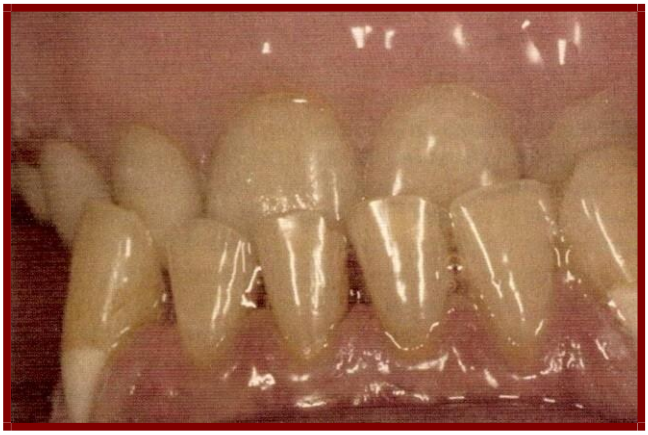


Figure 65: The mandibular incisors have overerupted beyond the occlusal plane in this patient of "combination syndrome".

Treatment Considerations

To place the maxillary incisors in their correct position, the mandibular anterior teeth need to be restored to the proper incisal plane. Endodontic therapy and crown lengthening procedures usually precede the restorations on the lower arch to obtain a retentive and esthetic restoration.

On occasion, the remaining roots of the mandibular anterior teeth are too short to consider for long-term prognosis, once the crown lengthening is performed. Under these conditions, extraction of the mandibular anterior teeth, alveoloplasty, and implant placement may be indicated.

When the arch form in the mandible is ovoid to tapered, five anterior implants may be adequate to serve as support for a completely implant supported overdenture (RP - 4). Hence the implants not only can replace the teeth extracted because of overeruption but also can replace the posterior missing teeth. This approach in the treatment of a combination syndrome eliminates the need for posterior bone grafts.

3) Mandibular Incisal Edge Position

The position of the lower anterior teeth is evaluated next. Normally, the incisal edges of the mandibular teeth contact the lingual aspect of the maxillary anterior natural teeth at the desired OVD position with the presence of a vertical overlap.

The *incisal guidance* is defined as the influence of the contacting surfaces of the mandibular and maxillary anterior teeth on mandibular movements. The incisal guide angle determines the amount of posterior tooth separation during mandibular excursions and should be steeper than the condylar guidance to separate the posterior teeth during mandibular excursions . Any planned prosthesis and associated compensating curves should therefore be developed within the confines of the incisal guidance.

The incisal guidance is evaluated on the mounted diagnostic models. The following considerations should be made while formulating the treatment plan:

- Steep incisal guidance helps avoid posterior interferences in protrusive movements.
- However, the steeper the incisal guide angle, the greater is the force applied to anterior single-tooth implant crowns. This force is of particular concern if the natural tooth was lost as a result of severe parafunction on a tooth with a steep incisal guidance.
- If the existing incisal guidance is shallow, recontouring or restoration of any posterior teeth that exhibit premature contacts during excursions may be necessary. This minimizes parafunctional forces applied on implant restorations in the region.

4) Existing Occlusal Planes

The occlusal plane is specifically evaluated in relationship to the final implant prosthesis. The relation of the horizontal posterior occlusal planes to the curves of Wilson (mediolateral) and of Spee (A -P) and to each other should allow harmonious occlusion with maximum intercuspation and canine or mutually protected occlusion in all excursions.

A pretreatment diagnostic wax-up is recommended to evaluate the need for alteration of the occlusal plane prior to implant placement. An occlusal plane analyzer may be used to evaluate and correct an improper occlusal plane. Occlusal analyzers are fabricated in several sizes. The average size corresponds to a 4 -inch sphere and provides a starting point for ideal curves of Wilson and Spee. Any discrepancy observed on the cast may be corrected in the mouth. The following steps are followed (Figs 66 to 68):

- A vacuum or press fit of an acrylic shell is pre pared over a duplicate diagnostic cast.
- The occlusal analyzer is used to identify discrepancies.
- A handpiece is used to grind the acrylic shell and protruding occlusal cusps on the duplicate diagnostic cast.
- The clear acrylic shell then is taken intraorally and inser ted over the teeth. Any cusp extending through the acrylic shell is recontoured to the level of the surrounding acrylic to correct the occlusal plane.

Steps in use of an occlusal plane analyzer

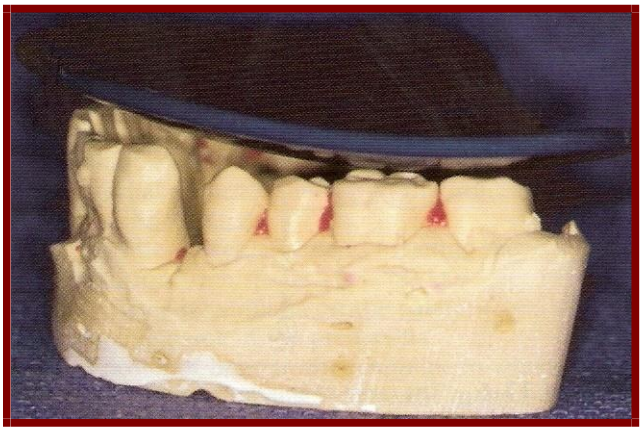


Figure 66: Occlusal plane is evaluated before restoration of the opposing arch

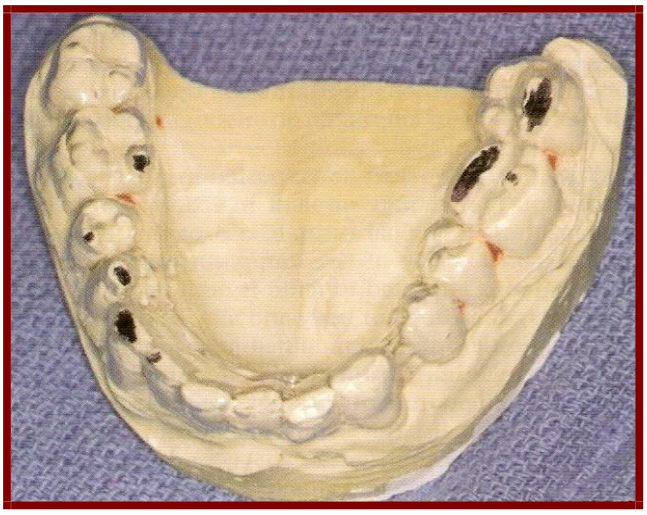


Figure 67: Mark on the cast the areas to be modified intraorally

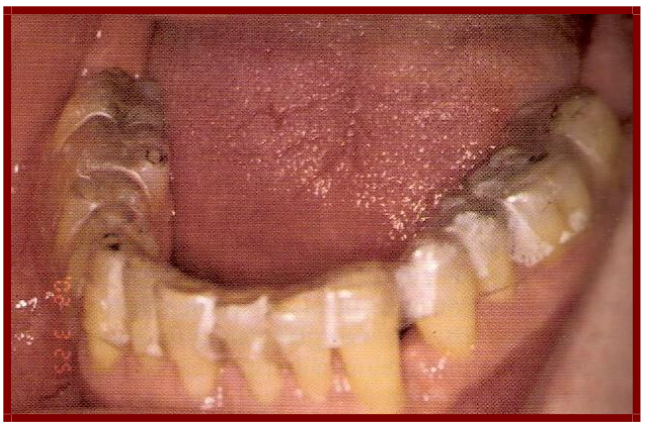


Figure 68: Correction is done intraorally using templat

Natural dentition opposing implant site

Due to lack of occlusal contacts, t he opposing teeth often supraerupt over a period of time. This results in a significantly reduced crown height space for the restoration. In addition, difficulty is encountered at time of surgery due to the limited interarch space. Treatment considerations of these extruded teeth include:

- Odontoplasty
- Endodontic therapy and crowns
- Extraction and implant placement

Partially edentulous posterior region with facial resorption

The implant placement in such patients is often more medial in relation to the central fossa of the n atural posterior teeth. The treatment plan may consider enameloplasty of the stamp cusps of the opposing teeth to redirect occlusal forces over th e long axis of the implant body.

Once the pretreatment overall tooth positions, OVD, and occlusal planes have been assessed, the following parameters are evaluated:

- Existing occlusion
- Crown height
- Maxillomandibular arch relationship
- Temporomandibular joint status
- Existing prostheses
- Arch form (ovoid, tapering, square)
- Implant permucosal position
- Missing teeth: location
- Missing teeth: number
- Lip line at rest, during speech and smile
- Soft tissue support

5) Existing Occlusion

The existing occlusion is evaluated best with face -bow mounted diagnostic casts and open mouth bite registration in centric relation.

Maximal intercuspation is defined as the complete intercuspation of the opposing teeth independent of condylar position. *Centric relation* is defined as a neuromuscular position independent of tooth contact with the condyles in an anterior superior position. C *entric occlusion* is defined as the occlusion of opposing teeth when the mandible is in centric relation . This may or may not coincide with maximal intercuspation position.

Controversy exists as to the necessity to have maximal intercuspation harmonious with centric relation occlusion. A vast majority of patients do not have such a relationship, yet they do not exhibit clinical pathologic conditions or accelerated tooth loss. The important consideration is the need to evaluate the existing occlusion to decide consciously whether the existing situation should be modified or maintained.

As a general rule, the more teeth replaced or restored, the more likely the restoration to centric relation occlusion.

For example, if a completely edentulous ma ndible is to be restored with an implant- supported fixed prosthesis, the centric relation occlusion position is preferred and allows the articulator and patient condition to be similar. However, when one anterior tooth is being replaced, the existing maxi mal intercuspation position is usually satisfactory for restoration, even though a posterior interference and anterior slide into full interdigitation is observed.

The underlying factor that helps determine the need for occlusal correction before restoration of the implant patient is the observation of negative symptoms related to the existing condition. The symptoms may include temperomandibular joint dysfunction,

tooth sensitivity or mobility, tooth fractures, tooth abfraction, and porcelain fracture. The fewer and less significant the findings, the less likely an overall occlusal modification is required before restoration.

6) Crown Height Space

For partially edentulous patients

The minimum crown height space needed for an implant - supported prosthesis should be 8 mm. However, the ideal crown height space is 9 to 10 mm in the posterior regions and 10 to 12 mm in the maxillary central incisor areas. This distance includes an ideal 3 mm of soft tissue, 2 mm of occlusal metal or porcelain thickness, and a 5 mm or greater high abutment (Fig 69).

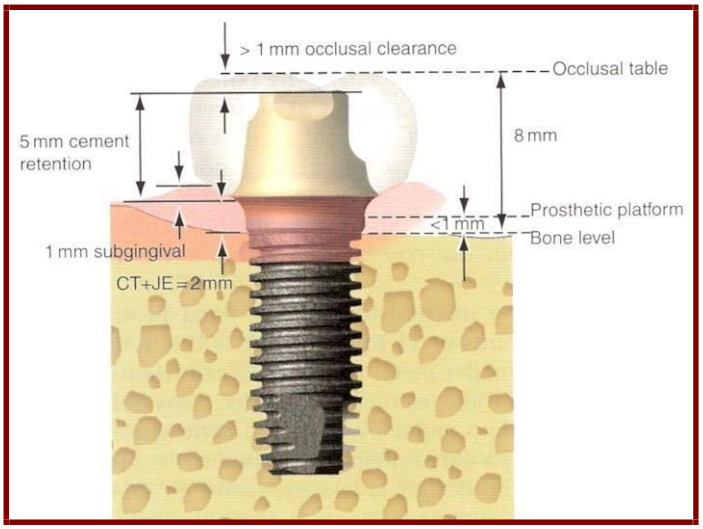


Figure 69: The minimum crown height space for a fixed restoration is 8 mm between the occlusal plane and the crestal bone.

For completely edentulous patients

An increased crown height space greater than 15 mm is often observed due to continued resorption of bone. Removable prostheses easily fill this space due to the sufficient bulk of acrylic and denture tooth. However, a similar crown height space may be of concern in fixed full-arch restorations due to the i ncreased moment forces on the implants. This problem is further magnified in the presence of a distal cantilever.

Prosthetic options in fixed full-arch restorations

1) Porcelain-metal restoration

The main problem encountered with this restoration is relat ed to the added bulk of metal used in the substructure to keep porcelain to its ideal 2 mm thickness. This amount of metal acts as a heat sink during casting procedures which results in porosities and increases the risks of fracture after loading.

Furthermore, when the casting is reinserted into the oven to bake the porcelain, the heat is maintained within the casting at different rates. Due to this, the porcelain cools down at different rates in different regions of the casting, with increased risk of porcelain fracture. In addition, the weight of the prosthesis is considerable, and because precious metals must be used to control

shrinkage or corrosion the cost of the restoration is increased dramatically.

2) Hybrid prosthesis

An alternative option in such situations is the hybrid prosthesis. Because acrylic acts as an intermediary between the porcelain teeth and metal substructure, the impact force during dynamic occlusal loading also may be reduced. Hence, hybrid prostheses are indicated for implant restoration in large crown height spaces as a general rule.

Augmentation

Excessive crown height space in completely edentulous patients may be corrected by the addition of onlay grafts to increase vertical bone height before implant placement. Autogenous or membrane grafts are preferred and often permit a wider body implant selection with the associated benefit of increased surface area.

Decreased crown height space

A reduced crown height space is most often observed due to extrusion of the opposing natural dentition. Its consequences are:

- Decrease in abutment height which may result in inadequate retention of the restoration.
- Increased flexure of the restoration which results in broken cement seals, loosening/ fracture of fixation screws, and porcelain fracture. The final restoration flexes inversely to the cube of the thickness of the material. A fixed prosthesis half as thick will flex 8 times as much.
- Inadequate bulk of restorative material for strength or esthetics.
- Poor hygiene conditions compromising long- term maintenance.

Treatment Considerations

Traditional prosthetic and restorative procedures are indicated to restore the proper plane of occlusion and crown height space , as previously described. However, on occasion even when the extruded opposing teeth are extracted, the crown height space still may be less than 7 mm due to overgrowth of the opposing alveolar process and soft tissue. Surgical intervention is then required.

If the opposing teeth are in the correct position and need not be altered or if the crown height space correction does not result in sufficient vertical space, one may gain addi tional space with osteoplasty or soft tissue reduction, provided adequate bone height

remains after the procedure for predictable implant supp ort. These surgical procedures may be performed at the time of implant placement to reduce time and number of surgical phases for the patient.

7) Maxillomandibular Arch Relationship

Arch relationships often are affected in edentulous ridges due to the facio-lingual direction of resorption. As a result, i mplants often need to be placed more l ingual in comparison to the original incisal tooth position. The final restoration is subsequently over-contoured facially to restore the incisal two- thirds for improved esthetics.

This results in a cantilevered force on the anterior implant body. The maxilla is affected more often than the mandible, because the incisal edge position cannot be modified and is dictated by esthetics, speech, lip position, and occlusion. Also, the hygiene of the prosthesis is compromised due to the overcontour.

Treatment Considerations

Anterior cantilevered crowns often require additional implants splinted together and an increase in the anteroposterior (A - P) distance between the most distal and most anterior implants to

compensate for the increased lateral loads and moment forces, especially during mandibular excursions.

Class II Relation

An anterior cantilever on implants in the mandibular arch may correct an Angle's skeletal Class II jaw relationship. To counteract this force multiplier, the treatment plan is modified by:

- Increase in implant number, size, and surface area of design.
- Increase in A-P distance between splinted implants.
- A RP-4 restoration may be indicated, rather than a FP-3, to prevent food impaction and to facilitate daily care.

Class III Relation

Because the edentulous premaxilla resorbs toward the palate, a Class III relationship is often observed. However, these patients often do not exhibit Class III mandibular mechanics (primarily vertical chewers with little to no anterior excursions during mastication or parafunction). To the contrary, these patients have a full range of mandibular excursions. This exerts significant lateral forces on the maxillary restoration, which is cantilevered off the implant base to obtain a Class I esthetic restoration.

Treatment Considerations

Additional splinted implants in the maxilla are advocated with the widest A-P distance available. This usually requires sinus graft procedures to be incorporated in the treatment plan.

Transversal Arch Relation

A posterior crossbite is commonly observed due to resorption of edentulous maxillary posterior arches toward the palate after tooth loss. This is pronounced when opposing a Division C – h atrophic mandible.

Treatment Considerations

Sinus grafts can restore available bone height for implant placement. However, the ridge still remains medial to the opposing mandibular tooth central fossa. Hence, the posterior teeth may be placed in a crossbite to decrease the moment forces developing on the maxillary posterior teeth.

8) Temperomandibular Joint

The TMJ status should be carefully evaluated for parafunction. Symptoms include pain and muscular tenderness experienced by the patient. Noises or clicking in the joint during opening, deviation of the mandible during jaw opening, and l imited jaw movements are signs of potential dysfunction.

Many patients with soft tissue-borne prostheses and TMJ dysfunction benefit from the stability and exacting occlusal aspects that implant therapy provide which is a valid treatment consideration wherever possible. [6]

9) Existing Prostheses

The esthetics of an existing prosthesis to be replaced by an implant-supported restoration should be evaluated for functional harmony and esthetics. If unacceptable to the patient, the reasons for dissatisfaction should be noted. A pretreatment prosthesis may be indicated for such patients.

An acceptable maxillary complete denture to be replaced may be used as a surgical template. It may also be used to decide between a fixed or removable prosthesis. [37] Usually, a removable overdenture is able to provide adequate lip support. The thickness of the labial flange of the existing denture may be removed to evaluate the difference in lip position and support while considering a fixed prosthesis (Figs 70 and 71). If additional lip support is required once the labial flange is eliminated, a hydroxyapatite, connective tissue, or alloderm labial onlay graft usually is indicated.

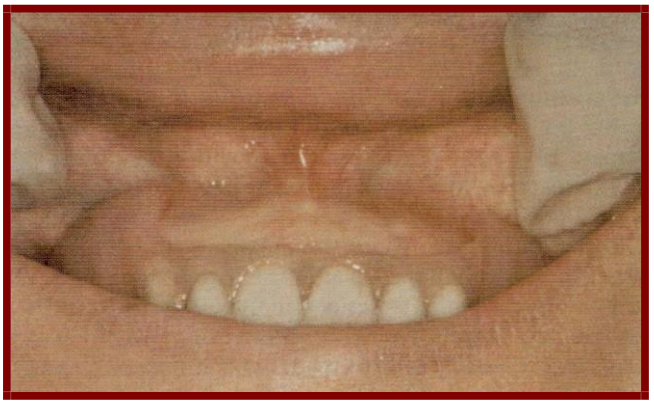


Figure 70: The labial flange of the maxillary denture may be removed to assess the soft tissue support

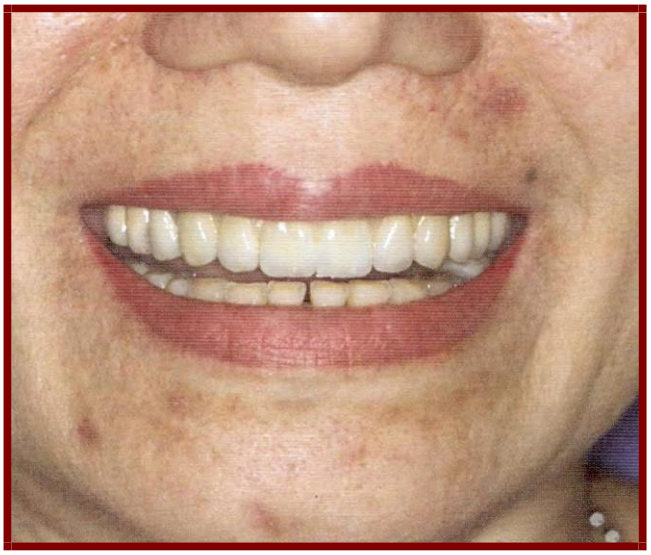


Figure 71: Adequate soft tissue support was attainable with a fixed full-arch prosthesis in this patient.

A removable partial denture (soft tissue-borne) opposing the proposed implant-supported prosthesis is of particular interest. This is due to the variation in occlusal forces as the underlying bone remodels. In addition, the patient may not even wear the partial denture in the future, which will modify the occlusal conditions dramatically. Continued maintenance and follow-up evaluations are indicated in such patients including relines and occlusal evaluation.

10) Arch Form

The edentulous arch form is described as ovoid, taperi ng, or square. The ovoid arch form is the most common, followed by the square, then the tapered form. The tapering arch form is most often found in skeletal Class II patients. The presence of a square arch form is more common in maxillary edentulous patien ts due to resorption of the premaxilla region.

The arch form is a critical element when anterior implants are splinted with posterior implants to minimize cantilever forces. The distance from the center of the most anterior implant to a line joining the distal aspect of the two most distal implants is called the *anteroposterior distance* or *A-P spread.*

A greater A-P spread is required in the presence of anterior cantilevers. Thus, a square arch form provides a poorer pro gnosis

than a tapered arch form in this regard. When five anterior implants in the mandible are used for prosthesis support, it has been recommended that the ratio of the distal cantilever to the A-P spread should not exceed 2:5. [27]

The other arch form to be considered is that of the replacement teeth which may be cantilevered off position for esthetic reasons. In this regard, a tapered arrangement of teeth offers the poorest prognosis due to the greater offset forces applied.

The worst combination of these two arch forms is observed in the edentulous maxilla when a square arch form of bone is used to restore a tapered arch form of teeth. The cantilever off the bone is greatest in this combination. The most ideal biomechanical arch form depends on the restorative situation:

- The tapering arch form of residual bone is favorable for anterior implants supporting posterior cantilevers due to a greater A-P spread.
- The square arch form of residual bone is preferred when canine and posterior implants are used to support anterior teeth in either arch.

As previously discussed, in the maxillary anterior region, implants often cannot be placed in their ideal location due to inadequate bone width. This may necessitate a more palatal implant placement. Sometimes, in advanced atrophy arches, the site chosen for implant placement is the canine eminence region. This results in an anteriorly cantilevered restoration to restore esthetics. Under these conditions, greater stress is placed on tapered arch arrangements of teeth compared with square arch forms. The following considerations assume importance:

- Additional implants of greater width and number to counteract the increase in lateral load and moment force.
- Not only are the canine implants necessary, but bone grafting with additional anterior implants is also advocated.
- Additional posterior implants in the first to second molar region, splinted to the most anterior implants, are highly recommended.

The recommended anterior cantilever dimension in the maxilla is less than that of the posterior cantilever in the mandible, because the bone is less dense and forces are directed outs ide the arch during excursions.

11) Implant Permucosal Position

An implant placed in the improper position can compromise the final results in terms of esthetics, biomechanics, and maintenance. The most compromising position for an implant is too facial because no prosthetic ‘ trick’ exists to mask it, resulting in compromised esthetics, phonetics, lip position, and function.

The permucosal position of the implant abutment is of particular importance for FP-1 prostheses . The ideal position is directly under the incisal edge position of the anterior natural tooth and under the central fossa of posterior natural teeth to be replaced.

The maxillary premolars may be in the esthetic zone in the presence of a high l ip line during smiling. Under these conditions , the implant body should be positioned buccal to the central fossa to enhance cervical esthetics without hygienic compromise. The central fossa may be widened under t hese conditions to avoid angled loads in centric occlusion.

An angled abutment may help improve the condition if the improper placement is not severe. However, the facio - gingival contour remains compromised. The angled abutment also increases the forces exerted at the crest of the bone. The labial cortical plate is much thinner than the lingual and has to resist a greater force in

this situation. Cervical bone loss and associated soft tissue recession are inevitable consequences.

A lingually positioned implant is more easily corrected in the final restoration. The occlusal forces usually are directed more longitudinal to the implant body, and the thicker lingual cortical bone provides initial stability and denser bone for improved force transfer at the implant-bone interface. In addition, because the implant body is often half the diameter of the adjacent teeth, the final crown is not necessarily overcontoured on the lingual aspect. However, the facial emergence of the crown will compromise hygiene, especially with an FP-1 prosthesis, because esthetic requirements will dictate some labial overcontour.

An implant placed too far mesial or too distal is of less consequence if the lip position does not expose the cervical third of the restoration. The final restoration then is constructed with the interproximal incisal two thirds ideal for esthetics, independent of implant placement. This may place the interproximal region directly over the implant abutment post. Hygiene is compromised, but the crown can be designed to allow daily care.

12) Missing Teeth: Location

The number and location of missing teeth influence the prosthodontic treatment plan of the patient.

1) For the most part, the second mandibular molar is not replaced in a posterior implant- supported prosthesis. The mandibular first molar is designed to occlude with the mesial marginal ridge of a natural second molar to prevent extrusion. Some of the reasons why mandibular second molars are not replaced are:

- 10% greater bite force
- 90% chewing efficiency forward of mid first molar
- Location of mandibular canal
- Less dense bone
- Greater submandibular fossa
- Less crown height for cement retention
- Less access for occlusal screws
- More difficult hygiene
- Cheek biting more common
- Crossbite more often present due to resorption
- More incision line opening after surgery
- Greater mandibular flexure

2) In contrast, maxillary second molars are restored with implants due to the following reasons:

- The poor bone density in the posterior maxillary region requires a greater number of implants to provide adequate surface area of bone-implant contact.
- A greater A-P spread often is required in the presence of anterior cantilevers.
- No risk of paresthesia exists as in the mandibular second molar.
- When an unopposed mandibular second molar extrudes, it may interfere with the distal aspect of a maxillary first molar during protrusion. To the contrary, when an unopposed maxillary second molar extrudes, it is distal to the mandibular teeth. Therefore excursions of the mandible proceed away from the maxillary second molar and are free of occlusal interferences.

3) A traditional fixed prosthesis replacement for a canine tooth is more at risk since the maxillary or mandibular lateral incisor is the weakest anterior tooth, and the first premolar is the weakest posterior tooth. A single-tooth implant is an ideal treatment plan under these conditions.

4) The treatment plan for an implant in the maxillary first premolar position must reflect careful consideration for the angulatio n of a natural canine when present. The 11- degree average distal inclination and distal curvature of the canine root brings the apex of the root into the first premolar implant area. Therefore, the implant should be angled to follow the root of the canine and prevent contact or perforation of the natural root. A shorter implant often is indicated, especially when a second premolar is also present.

13) Missing Teeth: Number

1) A traditional prosthodontic axiom indicates that a fixed prosthesis is not indicated if a canine and two or more adjacent teeth are missing. Hence, implants are indicated whenever the fol - lowing are missing:

- Canine, lateral incisor, and first premolar
- Canine, lateral, and central incisors
- Canine, first premolar, and second premolar.

In all three situations, an implant is indicated in the canine region. An additional implant also is placed in the more posterior edentulous site when premolars are missing or in the central incisor when three anterior teeth are missing. If stress factors are high, three implants may be indicated to replace the three teeth.

2) Replacement of three adjacent missing teeth in the pos terior regions of the mouth with a fixed bridge a lso usually is contraindicated due to the greater span between abutments. The deflection or bending of a fixed prosthesis varies directly with th e cube of the length. Therefore, a fixed prosthesis with one pontic deflects 8 times less than one with two pontics and 27 times less than a restoration with three pontics, all other fa ctors being equal (Fig 72). This greater movement increases the occurrence of porcelain fracture, cement breakage, or screw loosening in the restoration (Fig 73).

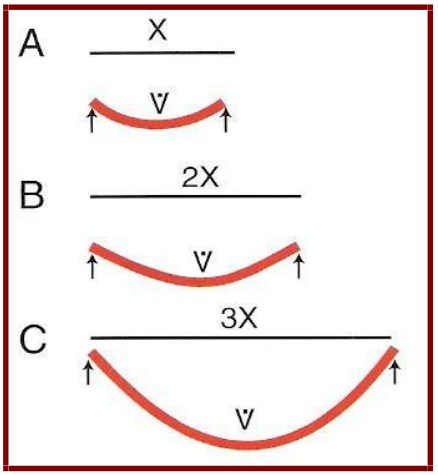


Figure 72: Metal flexure is related to the cube of the distance

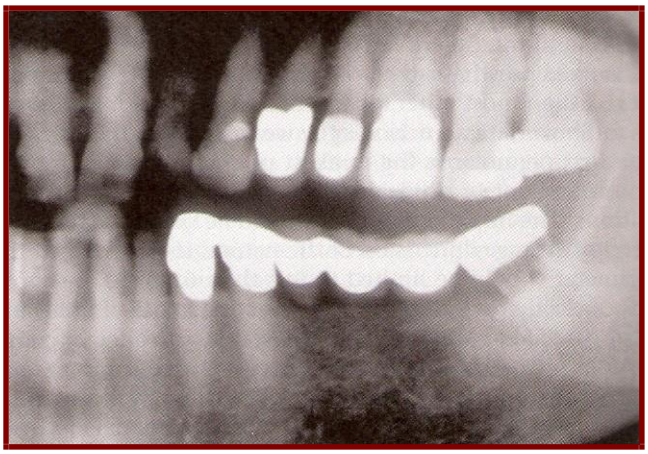


Figure 73: Pontics should not exceed beyond two in number for the same reason.

Independent implant prostheses are a better option to may reduce or eliminate the number of pontics while simultaneously increasing the number of abutments and distributing the forces more effectively (Fig 74). For all practical reasons, the number of posterior pontics in a fixed restoration should not extend beyond two, and even this condition is improved with independent implant - supported restorations.

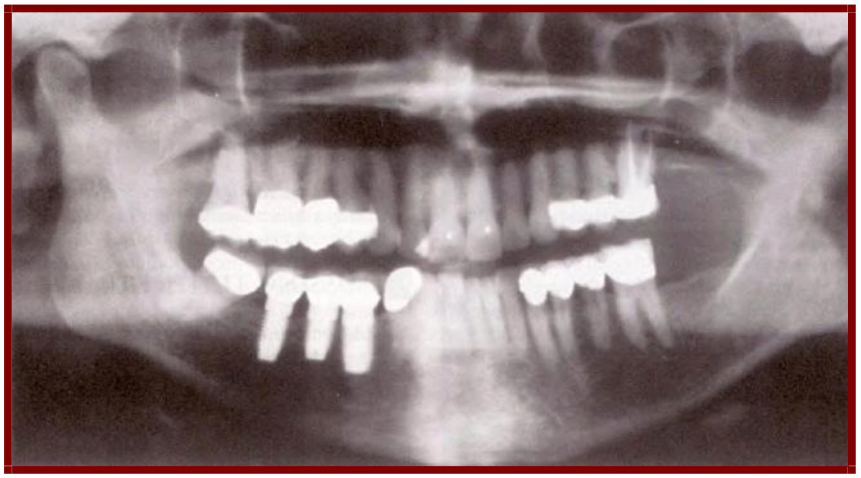


Figure 74: Additional implants provide a better alternative

3) The number of implants used to support a completely implant - supported restoration in the edentulous mandible usually ranges from five to nine in the mandible, with at least four of these implants inserted between the mental foramens.

4) A greater implant number in the completely edentulous maxilla is indicated to compensate for the less dense bone and more unfavor - able biomechanics and ranges from 6 to 10. At least two or three of these implants should be placed in the premax illa, depending on the arch shape and other force factors.

- For a square maxillary arch form (most favorable), implants may be placed in the canine position; whereas in an ovoid arch form, additional implants in the anterior region should be planned.
- A tapered anterior maxillary arch form combined with other force factors may require the placement of four implants from canine to canine.

All implants in either arch should be splinted together when fewer implants are used. The final restoration may be segmented (canine to canine and two posterior segments) when the number of implants permits so.

Posterior cantilevers in the fixed prosthesis should be limited in the maxilla and rarely extend more than one tooth. However, posterior cantilevers in full arch mandibular restorations are not uncommon, but the cantilever length rarely extends more than two teeth. Of course the number of cantilevered pontics in both arches depends directly on overall stress conditions.

14) Lip Lines

The lip line positions need to be assessed especially when anterior teeth are to be replaced. This includes assessment of the:

- Resting lip line
- Maxillary high lip line (smile)
- Mandibular low lip line (speech).

1) Resting lip line

A common removable prosthetic guideline is to have 1 to 2 mm of incisal edge show with the l ip at rest to give youthfulness to the smile. In general, a correlation between the resting lip line and the patient's age is observed. Older patients show fewer maxillary teeth at rest and during smiling but demonstrate more mandibular teeth during sibilant sounds.

A male shows fewer teeth than a female of the same age. In a 50- year- old man, the maxillary incisal edge is often level with the upper lip at rest. This is a similar position for a 60 - year-old woman. The maxillary incisal edge exposure at rest depends on the length and contour of the lip. The average upper lip measured form the floor of the nose is 20 to 22 mm for women and 22 to 26 mm for men. For a short upper lip, the standard guideline for in cisal edge 1 mm below the lip would not be acceptable because this would decrease the height of the maxillary arch.

The higher the lip bow, the greater incisor facial surface is seen on the patient, regardless of age. The lip bow in the center of the upper lip raises several millimeters on some females and is barely obvious on others. Men rarely exhibit an exaggerated l ip bow and therefore have a more consistent incisor edge position. The canine position at the corner of the lip is not affected by the l ip bow effect. As such, the canine is a more consis tent position and usually corresponds to the length of the resting lip position from 30 to 50 years of age in men and women.

In the natural dentition, the maxillary lip is most often longer than the incisal edge after the patient is 65 years old. However, most patients desire the maxillary teeth to be at least slightly visible. Extension of the maxillary tooth position is risky due to the consequences of an increased crown height on moment forces. If

pontics, rather than implants support the anterior crowns, the poor biomechanical condition is magnified.

An alternative to increasing the length of the anterior teeth may be to increase the thickness of the alveolar ridge through augmentation. This extra support brings out the lip and also raises the vermilion border. As a result the teeth are not longer, but the border of the lip is higher. The fuller maxillary lip also may look younger because vertical age lines may be reduced.

2) Maxillary high lip line (smile)

The maxillary high lip line is determined while the patient displays a natural, broad smile. The clinical charac teristics of an esthetic smile include a maximum of crown exposure (crowns of normal height), a normal tooth posi tion and alignment (lateral incisors may not be completely straight), a normal tooth form, and minimal gingival exposure (not unusual to show the interdental papillae). The normal clinical crown width/height ratio is 0.86 for the central incisor, 0.76 to 0. 79 for the lateral incisor, and 0.77 to 0.81 for the canine.

1) The FP-1 prosthesis, when indicated, attempts to reproduce a normal crown contour. However, with a high lip position during smiling, the esthetic requirements are much more demanding and

often mandate additional surgical steps to enhance the soft and hard tissues before the crown restoration.

2) The selection of an FP-2 and an FP- 3 fixed prosthesis often is based solely on the evaluation of the high lip line. A high lip position during smiling contraindicates an FP-2 restoration type because of poor cervical esthetics.

3) The labial flange of the patient's existing denture may be removed and the l ip position evaluated before completing the treatment plan for a fixed restoration. Onlay grafts with hydroxyapatite, connective t issue, or autogenous graft or allograft may be indicated to increase labial tissue thickness for proper lip support.

4) The cervical third of the maxillary premolars should also be assessed for appearance in the esthetic zone. The cervi cal third and gingiva of the premolar is often visible in patients with a high l ip line. These teeth should not appear too long or unnatural in height. If implants are considered, resorption may necessitate a more palatal placement in this area. The position of these teeth then may be too palatal and therefore affect the esthetic result. Grafts are indicated to improve the appearance in such a situation

3) Mandibular low lip line (speech)

The mandibular low lip position often is neglected, with disastrous esthetic results. Although the maxillary high lip line is evaluated during smiling, the mandibular low lip position should be assessed during speech.

In pronunciation of the *S* sounds or sibilants, some patients may expose the entire anterior mandibular teeth and gingival contour. Making the patient aware of these existing lip lines and impressing on them that these lip positions will be similar after treatment is recommended. A FP- 3 mandibular restoration is indicated to restore the patient with a low mandibular lip position.

15) Soft Tissue Ridge Support

The evaluation of the soft tissue support is of prime concern concerned in a RP- 5 prosthesis, which gains dual support from implants and edentulous ridges. The following factors should be evaluated:

Arch form size

Large jaws with little resorption provide a bet ter support than smaller sized ones with greater atrophy, whether in the maxilla or

mandible. Prosthesis support depends on the shape of the residual ridge and, in the maxilla, the palatal vault.

A square ridge form yields optimal resistance and stability. A relatively flat one represents a compromised factor for retention and stability, although support is still adequate. A steep palatal vault usually equates with poor stability

Ridge parallelism

The edentulous ridge parallel to the occlusal plane is most favorable for soft tissue support. If ridges are divergent, stability of the prosthesis will be greatly affected.

Soft Palate Type

A class I soft palate slope is favorable due to a long, gradual slope from the junction of the hard and soft palate. This slope allows a greater extension of the posterior palatal seal and enhances retention. A soft palate Class III which drops abruptly, compromises retention.

A greater number of unfavorable anatomical structures may direct the treatment plan towards a RP -4 prosthesis with greater implant support and no soft tissue support in order to address all the needs of the patient.

16) Treatment Prostheses

Treatment prostheses often are indi cated to obtain a diagnosis, improve soft t issue health before fabricating soft tissue - borne restorations, reestablish the OVD, and evaluate or treat TMJ dysfunction. In addition, a treatment prosthesis may be used to select a prosthetic option, to load bone progressively to improve its strength, and as a transitional restoration to protect a healing bone graft or implant. It also may help in evaluation of the psychological status of a patient before irreversible implant procedures.

Soft tissue management

Treatment prostheses can be used to improve the soft tissues used for support, stability, or retention of a RP-5 prosthesis.

A tissue conditioning treatment using the patient's existing denture as a treatment prosthesis usually is indicated to restore soft tissue health before making the final impression. Additional treatment such as surgical removal of excessive hypermobile tissues often is warranted before soft tissue conditioning.

In addition, tissue conditioners are used after implant surgery in regions under a removable prosthesis while the implant -bone interface heals. The tissue conditioner may respond to the swelling and tissue changes immediately after soft tissue reflection. At the suture removal appointment, the tissue conditioner is removed and

replaced with a sealed soft liner. In this way, the material stays soft over extended periods of time and is less likely to load the implant through the soft tissue. In addition, the soft liner is relieved over the implant site.

Occlusal Vertical Dimension

In long-term edentulous patients, the OVD may collapse gradually as a result of continued bone loss and prosthesis occlusal wear. Temporomandibular joint and myofascial dysfunction may be inevitable consequences of a reduced OVD. A treatment prosthesis to reestablish the proper OVD and assess a symptomatic joint is indicated in such situations (Figs 75 and 76).

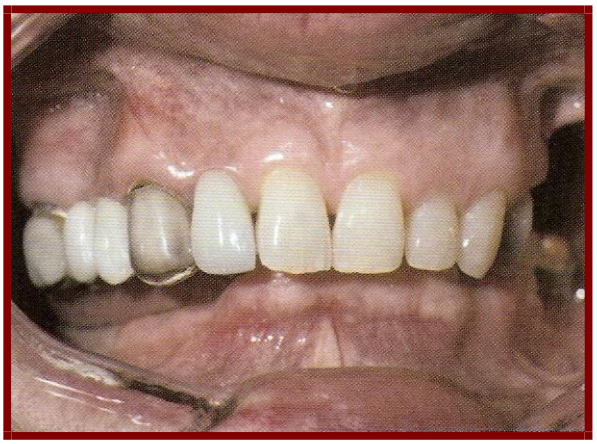


Figure 75: The patient has a collapsed OVD and poor occlusal plane.

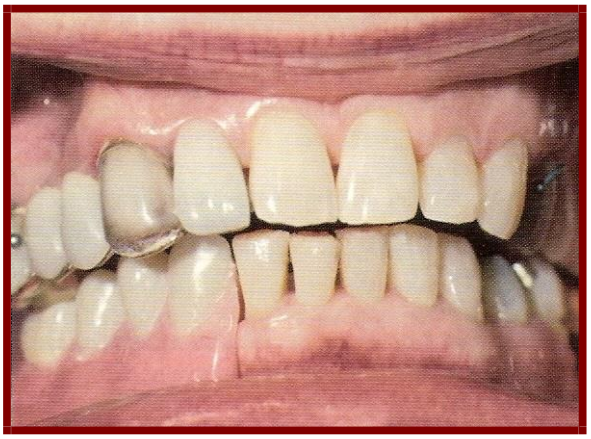


Figure 76: A treatment prosthesis should be used to reestablish the OVD

As the OVD decreases, the mandibular jaw rotates forward and closes in a more prognathic pseudo Class III relationship. To place the implants in the correct angulation, the OVD should be reestablished before implant surgery in the treatment prosthesis so as to establish the correct position of the teeth relative to the arch.

In the case of immediate loading, the transitional restoration is delivered at or soon after the implant surgery. The design of the prosthetic superstructure concomitant with the implant substructure is necessary. Hence, a treatment prosthesis is indicated to establish the proper OVD and tooth position before the placement of the implants and fabrication of the superstructure.

As the OVD increases, the maxillomandibular relationship evolves toward a Class II relationship, which influences the position or angulation of the implant. In addition, the location of an

overdenture bar may be influenced equally by variations of the OVD. The treatment prosthesis is useful to establis h the prosthetic position of the teeth.

Esthetic assessment

On occasion, a patient's desire for esthetic improvement may be demanding or unrealistic. In the completely eden tulous patient, one may use a treatment denture to satisfy these esthetic concerns before implant surgery. If the patient cannot be satisfied with the treatment prosthesis, realization of this fact before implant placement is better.

In edentulous patients, a high lip line in the maxilla or low lip line position in the mandible may influence the need for a specific gingival contour and color in the restoration, yet the mainte nance needs of the restoration may compromise the final esthetic result. A fixed full- arch restoration must be designed to allow access for proper hygiene procedures around the teeth and implants. In such situations, a treatment prosthesis may help determine whether an implant-supported removable prosthesis rather than a fixed restoration is required to satisfy the patient's esthetic goals and desires at the cervical of the restoration and yet may be removed to allow proper daily maintenance.

The maxillary vermilion border usually is altered by the loss of the maxillary anterior teeth. Once bone is also lost, the natural

support of the entire lip is often deficient and depends on the labial flange of the prosthesis. A fixed prosthesis may require an anterior cantilever away from the soft tissue in a horizontal and vertical dimension to provide this support. A treatment prosthesis can provide the information required to determine whether a fixed prosthesis will compromise esthetics, support, or hygiene in this region above the teeth.

A partially edentulous patient most often wears a fixed treatment prosthesis, which also acts as an interim prosthe sis. The dentist may use these fixed, transitional treatment restorations during bone grafts or healing of implants to decrease forces on the soft tissues and on the graft or healing implants.

Progressive Loading

Interim (provisional) acrylic restorations that gradually load bone may be considered treatment prostheses. These prostheses also assist in the determination of the final form and function of the final prosthesis, especially for completely edentulous patients for whom the treatment prosthesis may be the first f ull arch fixed restoration they have worn after several years of wearing a com plete denture. A decrease in crestal bone loss and decrease in implant failure, especially in soft bone types, are partic ular advantages with such treatment prosthesis.

Natural Teeth Adjacent to Multiple Implant Sites: Influence on Treatment Planning

A common prosthetic axiom is to provide the partially edentulous patient with a fixed prosthesis whenever possible. Implants can be used as an independent support for the rest oration or, on occasion, along with natural teeth in the same prosthesis. In either situation, the treatment plan is strongly influenced by the natural abutments adjacent to the edentulous site . A thorough evaluation of the natural teeth adjacent to the im plant site is therefore essential. While planning for an implant -supported restoration several factors need to be assessed:

1) Abutment options
2) Extract or maintain adjacent natural tooth
3) Adjacent bone anatomy
4) Cantilevers
5) Implants connected to teeth
    - Natural abutment mobility
    - Splinting natural abutments
    - Natural and implant pier abutments
6) Pier Abutments
7) Transitional abutments

1) Abutment Options: Implant vs. Tooth

The three most common causes of failure of traditional fixed prostheses are:

i) Caries and subsequent decay of the natural abutment

ii) Endodontic failure of the natural abutment

iii) Unretained or uncemented restorations

In comparison, implant abutments do not decay and do not require endodontic therapy. As a result, the 10 - year survival rates indicate a greater than 25% improved survival rate for implant prostheses as compared with conventional fixed partial dentures. Also, natural teeth respond to occlusal forces differently than implants as discussed below.

Thus, an independent implant restoration is the treatment of choice for almost every multiple-tooth partially edentulous site.

- When planning an implant- supported prosthesis, it is advisable to place an additional implant whenever possible, instead of using a natural tooth as one of the terminal abutments . The inherent mobility of the natural tooth may result in its intrusion.

2) Extraction or Maintenance of a Natural Tooth

Implant dentistry significantly influences the treatment plan philosophy in periodontal therapy. Advanced periodontal disease may now be addressed with extraction of questionable abutments, provided the resulting edentulous area offers sufficient bone for predictable implant placement and prognosis.

The periodontal health of the adjacent natural tooth is first evaluated using widely used periodontal indexes. The longevity of the tooth is then estimated based on which a decision has to be taken whether to either extract the tooth or to treat and maintain it. This decision is based on what is known as the '0 -, 5-, 10- year rule'.

Table 13: Extract or Maintain Natural Tooth:

0-, 5-, 10-Year Rule

Prognosis	Protocol
> 10 years	• Maintain the natural tooth. Do not extract. • Decide on potential as an abutment.
5-10 years	• Maintain the natural tooth. Carry out periodontal/ restorative therapy. • Independent implant-supported prosthesis is indicated. • If available implant support is not sufficient for an independent restoration, then include the natural tooth in the prosthesis – make it a '*living pontic'* by adding implants on each side and splint together.
< 5 years	➢ Extract the natural tooth. ➢ Graft the site. ➢ Plan for additional implant support.

3) Adjacent Bone Anatomy

In case of inadequate bone volume in the edentulous site adjacent to the natural tooth, the treatment plan has to be modified. The following options need to be considered:

i) Augmentation of the edentulous site (Fig 77)

This allows for an independent implant - supported prosthesis and is recommended wherever possible.

Figure 77: Augmentation is the treatment of choice when inadequate bone is available adjacent to the natural tooth.

Certain limitations to this approach may exist:

- Augmentation of bone in height is less predictable.
- If the natural tooth has a horizontal defect, the situation is more compromised since the bone augmentation in height will not occur above the position of the bone on the root.

An alternative for inadequate bone height is orthodontic extrusion of the natural tooth in addition to bone augmentation. The orthodontic movement will increase bone height next to the tooth and improve the prognosis of the bone graft. The natural tooth usually requires endodontic therapy and restoration after the orthodontic process.

If augmentation is not a predictable modality, the remaining three options are considered.

ii) Cantilever the missing tooth (pontic) to either two or more natural anterior teeth or to posterior implants. The posterior implants permit the replacement of more than one tooth but require atleast two implants (Fig 78).

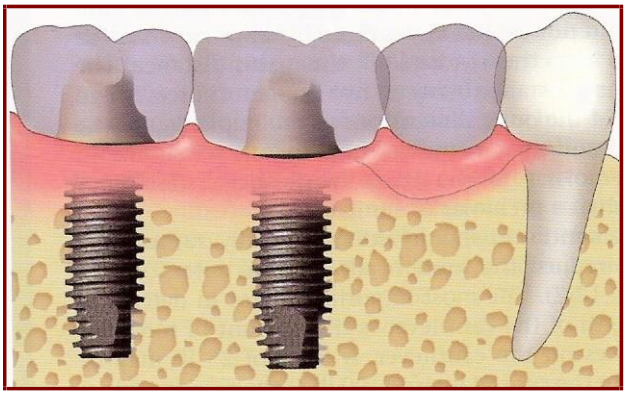


Figure 78: One option is to cantilever the pontic from posterior implants.

iii) If the natural tooth is nonmobile, insert an implant more distal and fabricate a three-unit fixed partial denture connecting th e implant to the tooth (Fig 79).

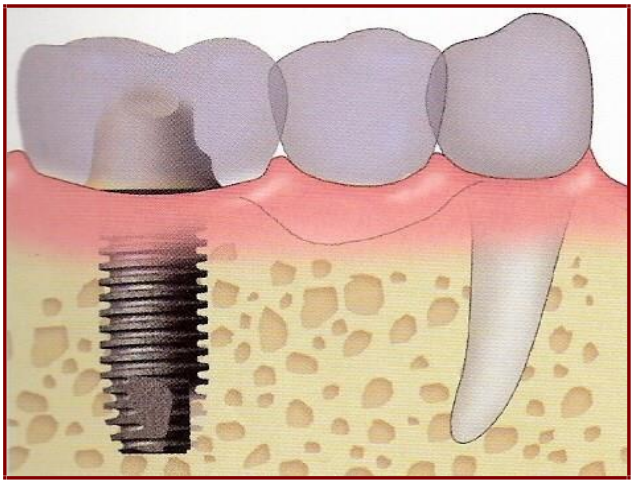


Figure 79: Another option is to connect a distal implant to the natural tooth.

iv) If the natural tooth is slightly mobile, insert an implant more distal and make a four-unit fixed partial denture by connecting the implant to two anterior teeth (provided the most anterior tooth is nonmobile) (Fig 80).

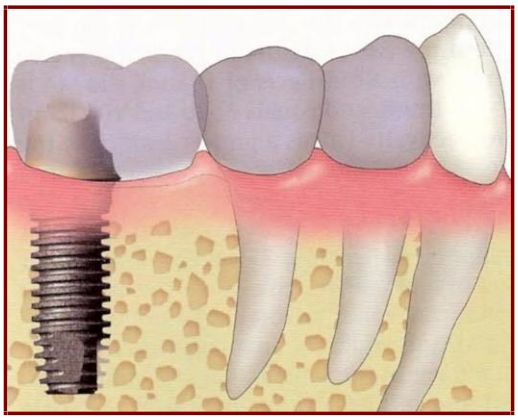


Figure 80: If the tooth is slightly mobile, additional anterior teeth should be splinted to the prosthesis.

Osteoplasty to gain additional bone width is not considered as a treatment option in the given situation since it may c ompromise the adjacent natural root support and increase the crown height of the final restoration.

4) Cantilevers

Cantilevers in fixed prostheses result in moment loads or torques on the abutments. The force on the cantilever may be compared with a Class I lever with the most adjacent abutment serving as the fulcrum.

The most common complication observed in cantilevered restorations is the uncementation of the abutment farthest from the cantilever. This occurs because the cement is about 20 times weaker in tension than in compression.

An important factor is the mechanical advantage of the cantilever:

$$\text{Mechanical advantage:} \quad \frac{\text{Length of the cantilever}}{\text{Distance between most anterior and most distal abutment}}$$

For example, if the implants are 10 mm apart and a distal cantilever of 15 mm is present, the MA is 1.5 times. A 25 lb compressive load is then magnified to a tensile load of 37.5 lb on

the most anterior abutment. The most distal abutment closest to the cantilever acts as a fulcrum and receives the sum of the two loads, or a compressive load of 62.5 lb.

The length of the cantilever should be ideally less than the distance between the two implants to keep the MA under 1 times this distance. The most common distance between two implants is 7 to 8 mm which corresponds to the diameter of a premolar crown. Thus, the size of the cantilever should not be greater than the size of a premolar of similar size.

The most important factor in determining the length of the cantilever is the amount of force the patient places on the cantilever. A force of 25 lb may be generated on the central incisors, 90 lb at the canine region, and 200 lb at the first molar site.

For example, in the first situation described previously, if the distance between the two implants is decreased to 5 mm with a cantilever of 15 mm, the MA is 3 times, and results in a force of 75 lb and 100 lb on the abutments respectively. This is a greater load than the first example. However, if the same first scenario occurred in a clenching patient with a 200 lb bite force instead of 25 lb, then the 1.5 MA would result in forces of 300 lb and 500 lb,

respectively, on the anterior and posterior implants, rather than 37 and 62.5 lb.

In other words, the amount of force generated against the cantilever is more critical than the other factors, including the cantilever length and MA. Ideally, a cantilever should extend mesially, rather than distally, to reduce the amount o f occlusal force generated.

Thus, the cantilever magnifies any other force factor presented and therefore should be used with caution.

Treatment Considerations

- Whenever used, the occlusion on the cantil evered pontics should be modified. All contacts during mandibular excursions need to be eliminated. The opposing arch should ideally be a denture, and lateral forces should be avoided on the cantilever.
- The implants should be standard to large in diameter (3. 75 mm or greater).
- The cantilever should not be used in patients with moderate or severe parafunction. Instead additional implants or grafting and implants positioned without cantilevers are better

options. Splinting the implants to adjacent teeth to eliminate the cantilever effect can also be considered.

Some situations in which cantilevered implant restorations have been recommended are: [5]

- Alignment problems
- To avoid extensive bone grafting
- Esthetic restrictions if present

5) Implants Connected to Teeth

Consider a situation where a patient is missing the first and second molars and the third molar is not present. Ideally, independent restorations with two implants of proper size and design are indicated. However, if adequate bone exists in the second molar region and distal half of the first molar but inadequate bone exists in the mesial half of the first molar, then independent implant restorations are not possible, and an additional premolar size pontic is required. Two treatment options then may be considered:

i) The pontic may be cantilevered from the anterior natural teeth or the posterior implants (with associated complications).
ii) The implant can be splinted to a natural tooth, if all other factors are favourable. This is a valid treatment option if:

- A Division C – h bone is present in the pontic region. The inadequate bone height adjacent to the natural tooth decreases the prognosis of a vertical bone graft.

- The posterior implants are of narrower diameter than usual in which case a cantilever is contraindicated. Either an additional implant or a natural tooth is required as an abutment for the fixed prosthesis. When an additional implant is not possible, then the posterior implants can be joined by a rigid connector to natural teeth within the prosthesis.

Natural Abutment Mobility

This is the principal factor influencing the decision to join implants and teeth. In the implant-tooth rigid fixed prosthesis, five components may contribute to the movement of the system:

- The implant
- The bone
- The tooth
- The prosthesis
- The implant / prosthetic components

Vertical Movement

Splinting a rigid implant to a natural tooth has caused concerns relative to the biomechanical differences between the implant and tooth (Fig 81).

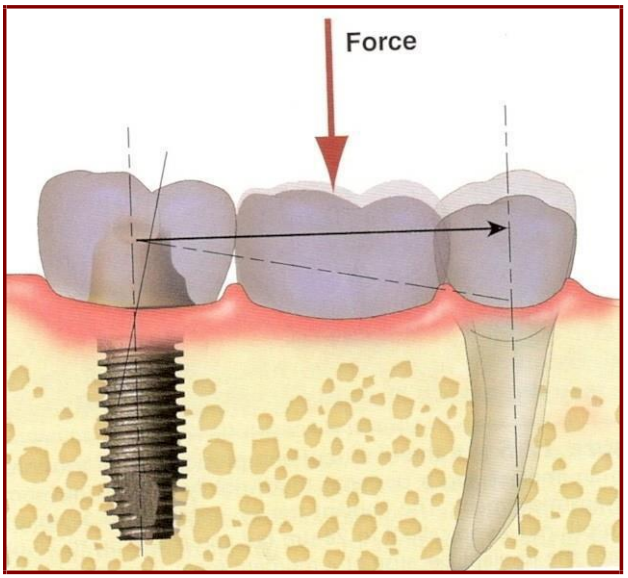


Figure 81: Because the tooth moves more than the implant, the implant may receive a moment force created by the "cantilever" of the prosthesis.

Although a healthy tooth exhibits 0 clinical mobility in a vertical direction, the actual initial vertical tooth movement is about 28 µm for both anterior and posterior teeth. The tooth can rotate up to 75 µm toward the implant because of a moment force. Comparatively, the vertical movement of a rigid implant is about 2 to 3 µm under a 10 -lb force and is due mostly to the viscoelastic properties of the underlying bone.

Because the tooth moves more than the implant, the implant may receive a moment force created by the ‘ cantilever’ of the prosthesis. Moreover, intrusion of the natural abutment may occur over sustained loading.

The fixed prosthesis that connects a tooth and implant also illustrates movement and helps to compensate for some d ifference in vertical movement (Fig 82). The metal in the prosthesis can flex from 12 to 97 µm, depending on the length of the span and the width of the connecting joints. Also, the abutment-to-implant component movement may be up to 60 µm because of abutment prosthetic screw flexure.

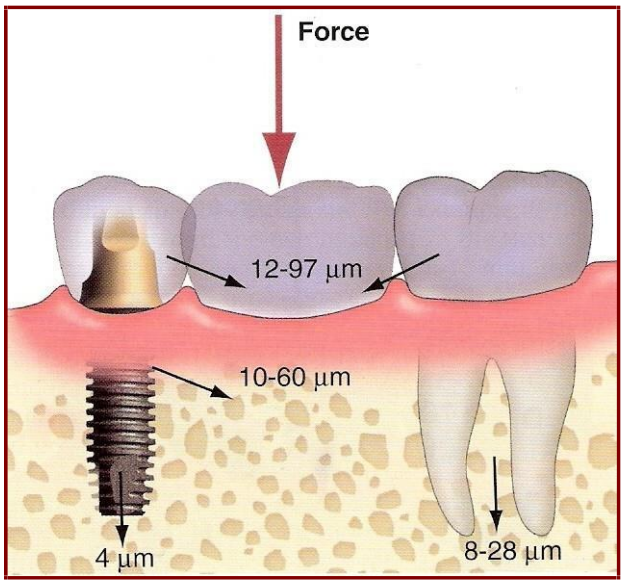


Figure 82: The prosthesis also has some inherent movement to compensate for the tooth movement.

As a result, a vertical load on the p rosthesis creates little biomechanical risk when joined to a nonmobile tooth because of the design. Various studies have reported comparable success rates to independent implant-supported restorations. Patient acceptance has been reported as being favorable. [3, 16, 35]

Horizontal Movement

Initial and secondary tooth movement is observed in a horizontal direction. The initial mobility is observed with a light force, occurs immediately, and is a due to the periodontal ligament. A healthy natural tooth may move laterally from 56 to 108 µm, with anterior teeth moving more than posterior teeth (Fig 83).

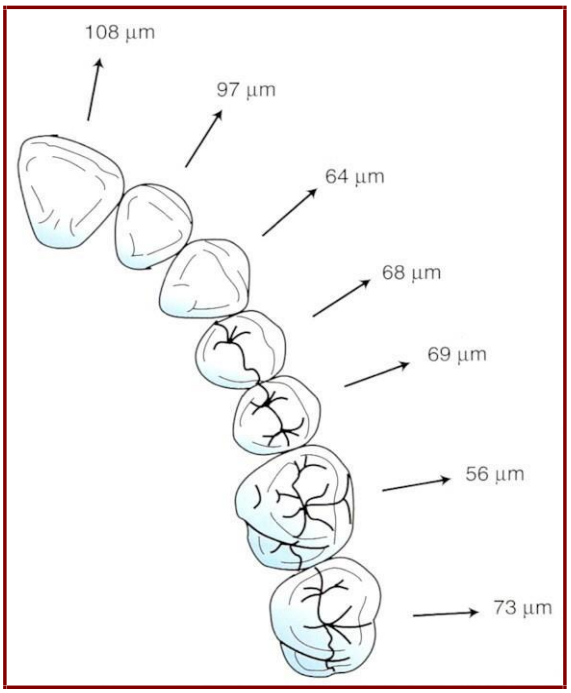


Figure 83: A healthy natural tooth may move laterally from 56 to 108 µm with anterior teeth moving more than posterior teeth.

If an additional force is applied to the tooth, a secondary movement is observed, which is related directly to the amount of force. It occurs due to the viscoelasticity of the bone and measures up to 40 µm under considerably greater force.

The implant-bone interface also exhibits lateral movement. Greater implant movement occurs in the mesio-distal direction (about 40 to 115 µm) as compared to movement in the labio-lingual direction (about 12 to 66 µm). This corresponds to lack of cortical bone between the implants in the mesiodistal direction as compared to the thicker lateral cortical plates present in the labiolingual dimension.

Bone density is a more influential factor in lateral movement as compared to implant length. Hence, the mobility of implants varies in direct proportion to the load applied and the bone density and reflects the elastic deformation of bone tissue.

Guidelines for Joining Implants to Teeth

There are two basic guidelines to be followed when splinting is considered as part of the treatment plan:

- Lack of observable clinical mobility of the natural abutment.
- Lateral forces should be avoided on the prosthesis.
- Use of a rigid connector in the assembly

Visual clinical evaluation by the human eye can detect movement greater than 90 µm. Movement up to this mark of 90 µm is considered as 0 clinical mobility.

A natural tooth with 0 clinical mobility can be connected rigidly to an osseointegrated implant because the implant, bone, and prosthesis compensate for the slight tooth movement. However, the occlusion should be modified to allow the initial occlusal contacts on the natural tooth so that the implant does not bear the major portion of the initial load.

A recent study has recommended that occlusal loading on the pontic region of the prosthesis be relived in order to redistribute stress within the implant. [26]

Lateral forces increase the amount of tooth movement and decrease the amount of implant movement in the facio-lingual direction. Horizontal forces placed on an implant also magnify the amount of stress at the crestal bone region. Implants should not be connected to anterior teeth because:

- Healthy anteriors exhibit + 1 mobility (90 to 108 µm). The implant is not able to withstand these exc essive horizontal forces (Fig 84).

- The lateral forces applied to the restoration during excursions (incisal guidance) are transmitted to the natural tooth and implant abutments.

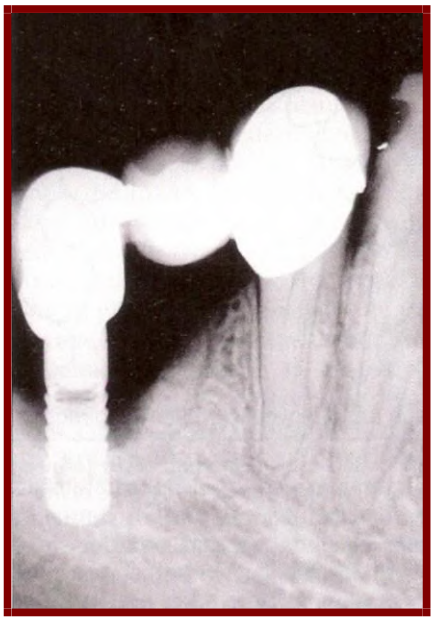


Figure 84: An implant joined to an anterior tooth is at greater risk of biomechanical overload.

When the natural abutment exhibits clinical mobility or conditions promote horizontal forces against the abutment tooth, two options may be considered:

i) Place additional implants and avoid the inclusion of natural abutments in the final prosthesis. This is most preferred.

ii) Improve stress distribution by splinting additional natural abutments until 0 clinical mobility is observed.

A study has reported that intrusion was not observed in teeth with a reduced periodontal support when connected to implants irrespective of the connector design. [39]

By and large, studies have supported the use of a rigid connector design in an implant-tooth supported restoration. [11, 39, 26] Tooth intrusion does not appear to take place when the tooth and the implant re firmly connected. An explanation offered for the occurrence of this phenomenon in connectors with freedom of movement is the risk of mechanical binding at the side walls. When the tooth is intruded during function, binding can arise, thereby inhibiting the rebound of the tooth. [11]

6) Pier (Intermediary) Abutments

A pier abutment is one between two other abutments and is also referred to as an intermediate abutment. The intermediate abutment may be an implant or a natural tooth and each type plays a different role in the overall treatment.

Implant Pier Abutment

When an implant serves as a pier abutment between two natural teeth, the difference in movement between the implant and tooth may increase the complication rate

The pier implant exhibits less movement than a terminal abutment and acts as the fulcrum of a Class I lever. (Figs 85 and 86). This problem is magnified by a longer lever arm when a pontic exists between the implant and tooth. An uncemented abutment, mostly the least mobile tooth or least retentive crown, is a common consequence.

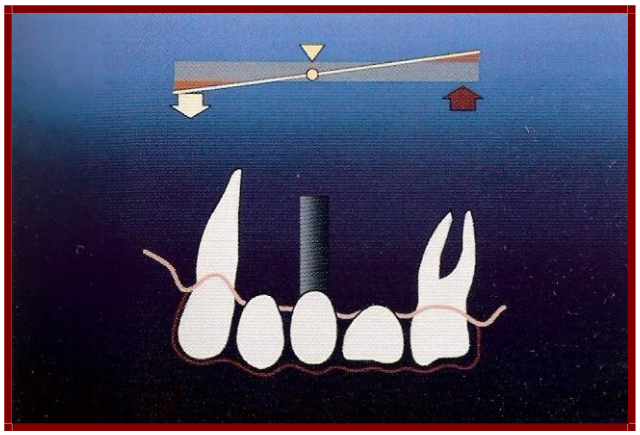


Figure 85: The more rigid implant may act as the fulcrum for a Class I lever. Implant pier abutments increase the biomechanical risks on the prosthesis.

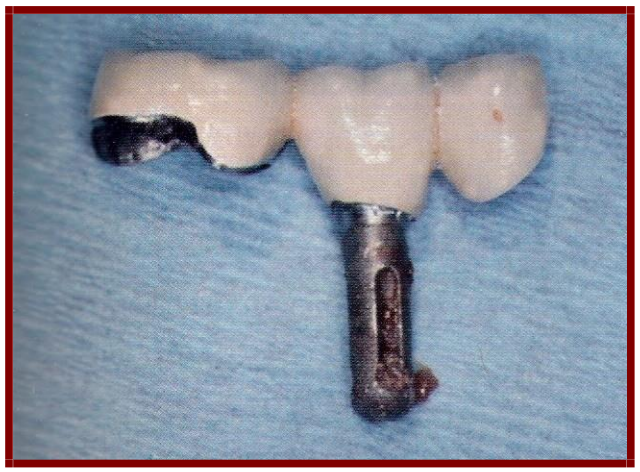


Figure 86: The cement seal on the natural tooth broke as a consequence. The implant was overloaded and failed

Treatment options available in this situation are:

1) Placing an additional implant in at least one of the sites next to a tooth to provide the support needed to fabricate an independent cantilevered implant-supported prosthesis.
2) Bone grafting in order to place implants in both terminal abutment locations next to the natural teeth (fig 87).

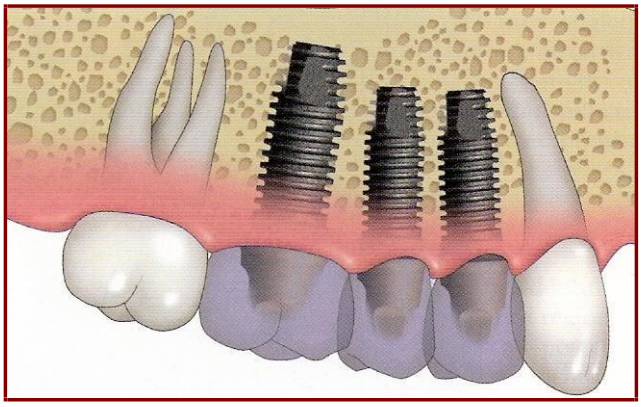


Figure 87: A better option is to graft adjacent sites to provide an independent implant-supported prosthesis.

3) A mobile or nonrigid attachment can be used to connect the implant and the least retentive crown. This prevents the implant pier abutment from acting as a fulcrum. As compared to a conventional fixed prosthesis, the nonrigid connector location is more flexible (Fig 88).

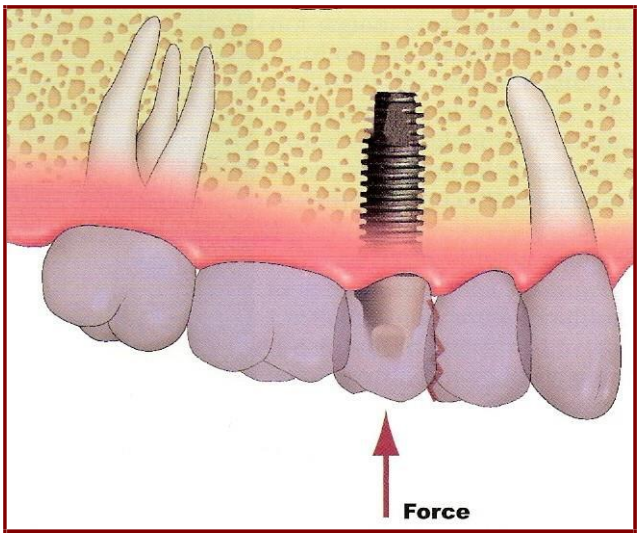


Figure 88: If this is not possible, a nonmobile attachment may be used to prevent the pier abutment from acting as a fulcrum.

Natural Pier Abutment

When a natural tooth serves as a pier abutment between two or more implants, the situation is completely different. The two implants support the load of the prosthesis alone and a fulcrum around the natural pier abutment is not set up (Fig 89).

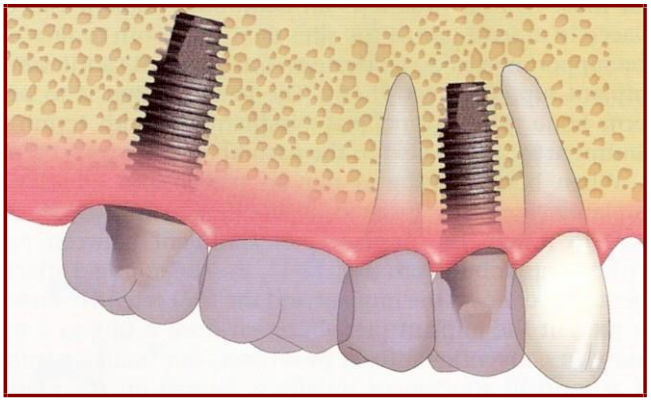


Figure 89: A natural pier abutment is at no such risk due to the rigid implant support. It is considered a "living pontic".

Effectively, the natural tooth becomes a living pontic. The natural tooth is not considered in the development of the treatment plan, other than the need to fabricate a crown rather than a pontic in the splinted prosthesis. An added advantage is the proprioce ptive capacity of the natural pier abutment.

7) Transitional Abutments

These are strategic teeth which can be used as interim (terminal) abutments to support a fixed temporary restoration. These natural teeth may be considered in this role even when if they have a poor prognosis.

Transitional abutments are indicated when bone augmentation procedures are needed before implant placement. For example, in a full- arch rehabilitation patient with a full-arch fixed restoration on periodontally involved teeth, a few short-term, asymptomatic teeth may be retained as transitional abutments while all others are extracted.

The main purpose is to provide the patient with a temporary fixed restoration rather than a full immediate denture while the grafting and implant insertion phases are performed. Once implant healing has occurred, the temporary natural abutments may be extracted and additional implants placed. The healed implants now

may support a transitional prosthesis. The main advantages of this approach are:

- Protection of the edentulous implant or graft site from mastication trauma.
- Use of a removable soft tissue-borne partial interim prosthesis is avoided.
- A fixed prosthesis maintains the patient throughout the treatment.

The disadvantages include:

- Extended treatment time with additional implant surgery.
- Risk of implant site contamination if flare up of the transitional abutments occurs.
- Increased risk for the initial implants because the foundation is not completely sufficient for support until the addit ional implants are healed.
- Additional cost incurred.

Abutment Evaluation

When considering an abutment (natural tooth or implant) for a reconstruction of an edentulous segment, several parameters need to be assessed as given below:

- Abutment size
- Crown/Root (Implant) ratio
- Crown height/Implant body ratio
- Tooth position
- Parallelism
- Caries
- Root configuration
- Root surface area
- Endodontic status
- Periodontal status

1) Abutment Size

When a tooth and implant are abutments within the same prosthesis, uncementation occurs more frequently on the implant. The parameters of retention for a prosthesis are similar for a tooth or implant and mainly are influenced by the diameter and height of the abutment.

Natural tooth

- Molars are more retentive than premolars bec ause of their increased surface area.
- Limited crown height due to limited interarch space also decreases retention. Splinting of teeth to compensate for the limited crown height compromises access for hygiene in the

interproximal areas. Instead, crown lengthening is indicated to improve retention, esthetics and hygiene maintenance of the restoration.

Implant

- Wider implant abutments are more retentive than narrower ones.
- A customized abutment of larger diameter can be used on an implant abutment of reduced height.
- Crowns of reduced size require minimal taper and additional retentive elements such as grooves or boxes to limit the path of insertion and direction of dislodgement of the prosthesis.

2) Crown/Root Ratio

The crown/ root ratio of natural teeth represents the height of the crown from the most incisal or occlusal level to the crest of the alveolar ridge around the tooth compared with the height of the root within the bone.

This criterion is most important when lateral forces are exerted against the crown, as in mandibular excursions. The lateral forces act as a Class I lever on the tooth, with the fulcrum at the crest of the bone. As the crown height increases, the root height decreases, creating a force multiplier. Thus, the crown/root ratio is

indicative of the risk of mobility and amount of additional stress the tooth may sustain when used as an abutment.

The most ideal crown/ root ratio desirable for a natural abutment is 1:2. The most common ratio observed clinically is 1:1. 5 with 1:1 being the minimum requirement . This is also applicable to natural teeth serving as abutments for an implant-tooth prosthesis.

3) Crown height/Implant body Ratio

Crown height/ Implant body ratio *is not considered in the same manner*. The height of an implant does not affect its mobility and does not affect its resistance to a lateral force . The implant captures the force at the crest of the ridge.

However, the crown height space is still an important factor to be considered since it acts as a vertical cantil ever and will magnify angled or lateral forces.

4) Tooth Position

If the natural abutment is an anterior tooth, then an implant - tooth supported prosthesis is not indicated due to potential greater mobility and lateral forces on the prosthesis. The most common indication for joining an implant to a natural tooth is in a posterior

edentulous site with a second or first premolar adjacent to the potential implant site.

Often, the natural tooth adjacent to the edentulous site may have drifted from its ideal position with tipping, rotation, or extrusion. Correction of the natural abutment position has to be then included in the treatment plan. This may take the form of either enameloplasty; alteration of the contact area; or even a crown.

5) Parallelism

Parallelism between implant and natural abutments is ideal. The path of insertion of a prosthesis that includes anterior and posterior abutments requires more extensive tooth preparation to achieve this parallelism. Several abutments may need endodontic therapy to achieve this goal.

For example, splinting of mandibular incisors may be required when considered as abutments in an implant-tooth supported prosthesis. These teeth are often crowded or rotated and may require endodontic therapy to achieve the desired path of insertion. Selective extraction may also be considered if the rotation creates an unfavorable environment for daily maintenance even after endodontic therapy and posts & crowns.

6) Caries

All carious lesions should be eliminated before impl ant placement, even when the teeth will be restored with crowns after implant healing for the final prosthesis.

7) Root Configuration

The root configuration of the natural abutment may affect the amount of additional stress the tooth may withstand with out potential complications.

Tapered or fused roots and blunted apexes (ex: maxillary second molar) have reduced ability to withstand additional occlusal loads required for a fixed prosthesis. Additional implants and independent implant supported restorat ions are indicated in such cases.

Root dilacerations (ex: maxillary canine) improve the support quality of a natural abutment but, at the same time, encroach on the adjacent available bone volume and increase the risk of implant placement. The best example is in the maxillary canine and first premolar region. Here, already the first premolar edentulous site is limited and the implant inserted should be shorter and should follow the angulation of the canine rather than that of the second premolar.

Roots with ovoid cross-section (ex: maxillary premolars) represent better abutments than those with circular cross section (ex: maxillary central incisor).

8) Root Surface Area

In general, the greater the root surface area of a proposed abutment tooth, the greater the support. Three adjacent pontics in a fixed implant-tooth supported prosthesis are to be avoided due to the increased metal flexure. This may cause porcelain fracture and uncemented restorations even if splinting of adjacent natural teeth is carried out. It is better to place additional implants to increase the support.

9) Endodontic Evaluation

A large number of implant failures may be attributed to adjacent endodontic failure of the natural teeth. This occurs because the healing implant interface is weaker than the previous bone condition and susceptible to complications.

If the pulpal status of a natural abutment is questionable, then endodontic therapy must be carried out before implant surgery. Otherwise, exacerbation of the lesion during early implant healing may result in a pathway of destruction to the adjacent implant site; implant failure; and extensive bone loss.

Apicoectomy procedures, when indicated, are best performed without use of amalgam retrograde fillings to avoid corrosion by-products in the area, which may contaminate the implant surface.

10) Periodontal Status

Routine periodontal evaluation of the natural abutment should be carried out. The implant surgeon should decide if periodontal therapy is indicated on the natural abutment at the same t ime as implant placement. A reduction in the number of surgical procedures is a noteworthy benefit to the patient; however, active infection should be minimized during implant placement.

List of Figures

14	Exposure of gingiva during smiling necessitates an FP-3 restoration	81
15	An FP-3 restoration replacing the interdental papillae with pink porcelain	82
16	The hybrid prosthesis is indicated when crown height is 15 mm or greater	83
17	An RP-4 restoration is completely supported by implants	84
18	An RP-5 restoration gains support from both implants and soft tissue	85
19	Available bone at the implant site is evaluated in terms of height (H), width (W), and length (L)	88
20	Height of available bone is measured from the crest of the edentulous ridge to the opposing landmark	89
21	Minimum bone width for a 4-mm root-form implant is 5-mm in midfacial and lingual region	91
22-23	The ideal mesiodistal length between an implant and tooth is 1.5-mm or more and 3-mm between each implant	92
24	Classification of available bone follows the natural resorption pattern	95
25	A panoramic radiograph of fixed maxillary and mandibular implant-supported restorations in Division A bone	96
26 - 27	Low profile overdenture design for Division A	97
28	A Division B ridge may be converted to Division A by osteoplasty	97

44	D4 bone requires increased surface area for bone-implant contact. Increasing the thread no. is one such method	119
45	Micromotion has caused fibrous tissue integration due to overload.	124
46	Marginal bone loss should be measured from the original crest	125
47	V-shaped stress patterns are visible on finite analysis	127
48	Photoelastic studies reveal similar patterns	131
49	Increasing the implant number reduces the force applied to each component	131
50	Crestal bone loss is more evident on an implant supporting a cantilever	134
51	Increasing thread no. increases the surface area of contact	135
52	The early crestal bone loss during the first year often stops at the first thread (or roughened area) and corresponds to the smooth collar	137
53	Severe bruxism with anterior and posterior wear	137
54	Repeated fractured restorations are a common finding in bruxism	141
55	Cervical abfraction seen in clenching	143
56	Severe bruxism is evident on this hybrid prosthesis	143
57	Fatigue failure has occurred due to sustained loading	144
58	Scalloped border of tongue is often found in a clenching patient	145

59	Wear facet on mandibular canine and slight notch in maxillary lateral incisor in a patient with mild bruxism	146
60	*Emgram* pattern of bruxism toward the left canine to central incisors.	147
61	Maxillary implant crown should be completely relieved from the guard	149
62	A soft reline material should be placed around an implant when the prosthesis is in the posterior region	150
63	Anterior tongue thrust habit	153
64	Posterior tongue thrust due to the loss of posterior teeth	153
65	The mandibular incisors have overerupted beyond the occlusal plane in this patient of "combination syndrome"	163
66-68	Steps in use of an occlusal plane analyzer	167
69	The minimum crown height space for a fixed restoration is 8-mm between the occlusal plane and the crestal bone	171
70	The labial flange of the maxillary denture may be removed to assess the soft tissue support	179
71	Adequate soft tissue support was attainable	179
72	Metal flexure is related to the cube of the distance	188
73	Pontics should not exceed beyond two	189
74	Additional implants provide a better alternative	189
75	The patient has a collapsed OVD and poor occlusal plane	198

76	OVD restablished using treatment prosthesis	199
77	Augmentation is the treatment of choice when inadequate bone is available adjacent to the natural tooth	206
78	One option is to cantilever the pontic from posterior implants	207
79	Another option is to connect a distal implant to the natural tooth	208
80	If the tooth is slightly mobile, additional anterior teeth should be splinted to the prosthesis	208
81	Because the tooth moves more than the implant, the implant may receive a moment force created by the “cantilever”	214
82	The prosthesis has some inherent movement to compensate for the tooth movement.	215
83	A healthy natural tooth may move laterally from 56 to 108 μm	216
84	An implant joined to an anterior tooth is at greater risk of biomechanical overload	219
85	Implant pier abutments increase the biomechanical risks on the prosthesis	221
86	The cement seal on the natural tooth broke as a consequence	221
87	A better option is to graft adjacent sites to provide an independent implant-supported prosthesis	222
88	A nonmobile attachment may be used to prevent the fulcrum action of the implant	223
89	A natural pier abutment is at no such risk	223

Summary and Conclusions

The discipline of implant dentistry has without a doubt enhanced dental health care. Various treatment options are now available for restoration of an edentulous region. Dental implant restorations have been shown to have the hi ghest survival rate as compared to any other type of prosthesis for the replacement of missing teeth.

Associated with these benefits is an added responsibility on the implant practitioner since implant surgery is an invasive procedure. The treatment planning for an implant restoration is unique regarding the number of variables that may influence the therapy. Of prime importance is recognition of the fact that a definitive treatment plan should be developed sequentially in order to ensure the best possible service.

References

1. **Smith DE, Zarb GA** . Criteria for success of osseointegrated endosseous implants. J Prosthet Dent 1989; 62: 567 – 572.
2. **Dharmar S** . Locating the mandibular canal in panoramic radiographs. Int J Oral Maxillofac Implants 1997; 12: 113 - 117.
3. **Garcia LT, Oesterle LJ** . Natural tooth intrusion phenomenon with implants. Int J Oral Maxillofac Implants 1998; 13: 227 – 231.
4. **Wallace RH** . The relation between cigarette smoking and dental implant failure. Eur J Prosthodont Rest Dent 2000; 8: 103 – 106.
5. **Becker CM, Kaiser DA** . Implant- retained cantilever fixed prosthesis: Where and when. J Prosthet Dent 2000; 84: 432 – 435.
6. **Bergendal T, Magnusson T** . Changes in signs and symptoms of temporomandibular disorders following treatment with implant-supported fixed prosthesis: A prospective 3 year follow-up. Int J Prosthodont 2000; 13: 392 – 398.
7. **Hatley CL, et al** . The effect of dental implant spacing on peri- implant bone using the rabbit tibia model. J Prosthodont 2001; 10: 154 – 159.

8. **Dula K, et al** . The radiographic assessment of implant patients: decision- making criteria. Int J Oral Maxillofac Implants 2001; 16: 80 – 89.
9. **Andersen E, et al** . A prospective clinical study evaluating the safety and effectiveness of narrow diameter threaded implants in the anterior region of the maxilla. Int J Oral Maxillofac Implants 2001; 16: 217 – 224.
10. **Khayat PG, Hallage PGH, Toledo RA** . An investigation of 131 consecutively placed wide screw – vent implants. Int J Oral Maxillofac Implants 2001; 16: 827 – 832.
11. **Lindh T, et al** . Tooth-implant supported fixed prosthesis: A retrospective multicenter study. Int J Prosthodont 2001; 14: 321 – 328.
12. **Gross MD, Nissan J** . Stress distribution around maxillary implants in anatomic photoelastic models of varying geometry. Part 2. J Prosthet Dent 2001; 85: 450 – 454.
13. **Friberg B, Ekestubbe A, Sennerby L** . Clinical outcome of Branemark system implants of various diameters: A retrospective study. Int J Oral Maxillofac Implants 2002; 17: 671 – 677.
14. **Kumar A, Jaffin RA, Berman C** . The effect of smoking on achieving osseointegration of surface- modified implants: A clinical report. Int J Oral Maxillofac Implants 2002; 17: 816 – 819.

15. **Sugerman PB, Barber MT** . Patient selection for endosseous dental implants: Oral and systemic considerations. Int J Oral Maxillofac Implants 2002; 17: 191 – 201.
16. **Tangerud T, Gronningsaeter AG, Taylor A** . Fixed partial dentures supported b natural teeth and Branemark system implants: A 3 year report. Int J Oral Maxillofac Implants 2002; 17: 212 – 219.
17. **Wang T, et al** . Effects of prostheses materials and prostheses splinting on peri-implant bone stress around implants in poor - quality bone: A numeric analysis. Int J Oral Maxillofac Implants 2002; 17: 231 – 237.
18. **Davis DM, Packer ME, Watson RM** . Maintenance requirements of implant-supported fixed prostheses opposed by implant- supported fixed prostheses, natural teeth, or complete dentures: A five year retrospective study. Int J Prosthodont 2003; 16: 521 – 523.
19. **Tosun T, Karabuda C, Cuhdarolu C** . Evaluation of sleep bruxism by polysomnographic analysis in patient s with dental implants. Int J Oral Maxillofac Implants 2003; 18: 286 – 292.
20. **Morneburg TR, Proschel PA** . In vivo forces on implants influenced by occlusal scheme and food consistency. Int J Prosthodont 2003; 16: 481 – 486.

21. **Tada S, et al**. Influence of implant design and bone quality on stress/strain distribution in bone around implants: A three dimensional finite element analysis. Int J Oral Maxillofac Implants 2003; 18: 357 – 368.
22. **Bryant SR, Zarb GA** . Crestal bone loss proximal to oral implants in older and younger adults. J Prosthet Dent 2003; 89: 589 – 597.
23. **Tawil G, Younan R** . Clinical evaluation of short machined-surface implants followed for 12 – 92 months. Int J Oral Maxillofac Implants 2003; 18: 894- 901.
24. **Prosper L, et al** . Four year follow up of larger diameter implants placed in fresh extraction socket using a resorbable membrane or a resorbable alloplastic material. Int J Oral Maxillofac Implants 2003; 18: 856 – 864.
25. **Kreisler M, et al** . Residual ridge resorption in the edentulous maxilla in patients with implant- supported mandibular over dentures: An eight year retrospective study. Int J Prosthodont 2003; 16: 295 – 300.
26. **Lin C, Wang J** . Non l inear finite element analysis of a splinted implant with various connectors and occlusal forces. Int J Oral Maxillofac Implants 2003; 18: 331 – 340.
27. **Brosky ME, et al** . The anterior cantilever in the implant - supported screw- retained mandibular prosthesis. J Prosthet Dent 2003; 89: 244 – 249.

28. **Geramy A, Morgano SM** . Finite element analysis of three designs of an implant supported molar crown. J Prosthet Dent 2004; 92: 434 – 440.

29. **Hekimoglu C, Anil N, Cehreli MC** . Analysis of strain around endoosseous dental implants opposing natural teeth or implants. J Prosthet Dent 2004; 92: 441 – 446.

30. **Himmlova L, et al** . Influence of implant length and diameter on stress distribution: A finite element analysis. J Prosthet Dent 2004; 91: 20 – 25.

31. **Penarrocha M, et al** . Radiologic study of marginal bone loss aound 108 dental implants and its relationship to smoking, implant location, and morphology. Int J Oral Maxillofac Implants 2004; 19: 861 – 867.

32. **Vigolo P, et al** . Clinical evaluation of small-diameter implants in single-tooth and multiple-implant restorations: A 7 year retrospective study. Int J Oral Maxillofac Implants 2004; 19: 703 – 709.

33. **Zinsli B, et al** . Clinical evaluation of small-diameter ITI implants: A prospective study. Int J Oral Maxillofac Implants 2004; 19: 92 – 99.

34. **Mordenfeld MH, et al** . A retrospective clinical study of wide-diameter implants used in posterior edentulous areas. Int J Oral Maxillofac Implants 2004; 19: 387 – 392.

35. **Kronsterom M, Trulsson N, Soderfeldt B** . Patient evaluation of treatment with fixed prosthesis supported by implants or a combination of teeth and implants. J Prosthodont 2004; 13: 160 – 164.

36. **Worthington P** . Injury to the inferior alveolar nerve during implant placement: A formula for protection of the patient and clinician. Int J Oral Maxillofac Implants 2004; 19: 731 – 734.

37. **Neves FD, Mendonca G, Fernandes AJ** . Analysis of influence of lip line and l ip support in esthetics and selection of maxillary- supported prosthesis design. J Prosthet Dent 2004; 91: 286 – 288.

38. **Goene R, et al** . Performance of short implants in partial restorations: 3 year follow-up of osseotite implants. Implant Dent 2005; 14: 274 – 280.

39. **Cordaro L, et al** . Retrospective evaluation of complete arch fixed partial dentures connecting teeth and implant abutments in patients with normal and reduced periodontal support. J Prosthet Dent 2005; 94: 313 – 320.