Chapter 6

# Immediate Loading in Implant Dentistry

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Additional information is available at the end of the chapter

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## 1. Introduction

Planning for immediate implant placement requires an accurate diagnosis and specific case selection [1-3]. Adequate planning can be accomplished using the various technologies that are available to us today, and it is important to remember that any alteration to position in relationship to the prosthesis used during planning can compromise the final result with alteration of occlusion, esthetics and biomechanics resulting. In order to accurately plan, a thorough clinical evaluation will be necessary and should include assessment of smile line, gingival morphology, the inter-arch relationship, condition and gingival margin positions of adjacent teeth, as well as supporting tissue conditions [4-6].

If the presenting conditions are deemed unfavorable, it is important that corrections be made via reconstruction of soft tissue, bone, and tooth positioning. An adequate amount of bone is important because a deficiency can jeopardize stability and lead to recession, loss of papilla and inadequate positioning; an inadequate amount of soft tissue will lead to a poor esthetic outcome [7-9]. Therefore, when bone quality and quantity are not sufficient, you must use regeneration techniques during the initial phase of treatment such as guided bone regeneration, orthodontics, and/or grafting. Other important things to be considered for immediate loading include the implant having primary stability [10,11]. Things that would contraindicate immediate loading include lack of primary stability, parafunction, pathology in the region of implant placement, and systemic alterations such as severe periodontal disease, poor oral hygiene, and smoking. Careful evaluation must be completed before immediate placement and loading be considered.

## 2. Immediate loading

### 2.1. Concepts and protocols

Ever since dental implants were first successfully employed in restoring completely edentulous mandibles in 1951, implant supported dental rehabilitations of various designs and complexity have been shown to be a reliable and predictable treatment option for both partially and fully edentulous patients [12-14]. The original Branemark protocol dictated that the initial phase of implant integration be at least 4 to 6 months before any restoration was placed [15]. "Conventional loading", as it is now known, is a reliable, safe, predictable, and accepted treatment modality that has been used as a point of comparison for other dental implant loading protocols.

Within the last decade, clinicians have increasingly begun to explore the possibilities of decreasing treatment time by early placement of the implant-supported restoration, or by placing implants in extraction sockets at the time of extraction [16-18]. Investigators are now increasingly reporting protocols designed to promote shortened treatment periods for implant-supported prostheses.

The concept of implant immediate loading includes all of the advantages of a one stage surgical approach. Also, during the osseointegration process, the patient does not have to use a removable denture, which increases function, speech, stability, comfort and improves certain psychological factors [19]. Splinted implants can decrease the risk of overload to each implant because of the greater surface area and improved biomechanical distribution [20,21].

The primary goal for immediate loading is establishment of direct bone implant contact. The terminology when it comes to immediate loading can sometimes be ambiguous and there many classifications in the literature, so it is important to understand the different techniques that can be used [22]:

#### *2.1.1. Terminology for the timing of implant loading*

**Immediate loading:** The placement of implants and insertion of restorations are completed in the same day.

**Early loading:** The restoration is connected to the implants at a second procedure but earlier than the conventional healing period of 3 to 6 months; time of loading should be considered in days/weeks.

**Delayed loading:** The restoration is connected at a second procedure after a conventional healing period of 3 to 6 months.

#### *2.1.2. Terminology for implant loading*

**Occlusal loading:** The crown/bridge is in contact with opposing dentition in centric occlusion.

**Nonocclusal loading:** The crown/bridge is not in contact in centric occlusion with opposing dentition in centric occlusion.

The concept of an immediate restoration includes a nonsubmerged first stage surgery and also implies that the occlusal surfaces and implants are loaded with a provisional of definitive restoration [23-25]. A delayed or staged loading refers to an implant prosthesis with occlusal load after more than 3 months (mandible) or 6 months (maxilla) post-implant insertion. Using a delayed approach allows you to use a 2 stage surgical procedure that covers implants with tissue or one stage approach that exposes a portion of the implant at the initial surgery.

### 2.2. Factors affecting time of loading

Some of the variables that can impact your ability to immediately load include surgical trauma, bone loading trauma, and treatment plans related to implant number. Alveolar and residual bone has a cortical and trabecular component that can be modified by modeling and remodeling. Remodeling allows the bone to respond to its local environment or allows bone repair after traumatic situation [26]. The bone is generally lamellar bone but woven bone might occur during the repair process. Typically, lamellar bone and woven bone are the primary bone tissue types observed around a dental implant. Lamellar bone and woven bone are the primary bone tissue types found around a dental implant. Lamellar bone is organized, highly mineralized and is the strongest bone type. Woven bone is unorganized, less mature, less mineralized and has lower strength and is more flexible [26]. Woven bone can form at a rate of 60μm (micrometers) per day, whereas lamellar bone forms at a rate of up to 10μm per day.

The rationale behind immediate loading is not only to reduce the risk of fibrous tissue formation but also to promote lamellar bone maturation to sustain a continued occlusal load. So when compared to the 2 stage approach, the repair of the implant is separated from the early loading response by 3-6 months. The process of osteotomy preparation and implant insertion causes a regional acceleratory phenomenon of bone repair around the implant interface [26]. Therefore, the organized lamellar bone in the preparation site becomes woven and unorganized next to the implant and at 4 months the bone is still only 60% mineralized lamellar bone- this is sufficient in most bone types and situation for implant loading.

The concept of immediate loading challenges the conventional load-free healing time of 3-6 months before the insertion of restoration. The bone in the thread design is stronger on the day of implant placement as opposed to 3 months later as more mature lamellar bone exists in the implant threads. However, the cellular connection between the implant surface and bone cells does not exist yet [26,27]. On the day of implant placement, there is residual cortical and trabecular bone around the implant and the implant has some contact with this prepared bone. Surgical trauma triggers early cellular repair and increased vascularization to stimulate repair process to injured bone [26,27]. Woven bone formation by appositional growth may start to form as early as the second week after implant placement at a rate of 30-50μm per day. Approximately 3-5 weeks after implant placement, the implant bone interface is weakest and at highest risk of overload since the implant-bone interface is least mineralized and unorganized during this time.

### 2.3. Risk factors for immediate loading

It has been found that immediate loaded failure occurred between 3-5weeks post-operative from mobility without infection [28-29]. The risk of immediate occlusal overload can be decreased by utilizing some techniques such as having more vital bone in contact with the implant interface, minimizing the surgical trauma at implant placement, including thermal injury and mechanical trauma that may result in microfracture of bone during implant placement. In addition, the microfracture of bone may lead to osteonecrosis and possible fibrous and granulation tissue encapsulation around the implant. Death of osteoblasts has been reported to occur at 40 °C [30-31].

Sharawy et al. [32], reported that heat generated in bone next to implant drills depends on design and revolutions of the drill. It was found that the drill rpm of 2500 generated less heat than 2000 rpm and 1250 rpm caused the highest heat and the longest recovery period regardless of drill design. Some other factors that need to be entertained to keep heat minimum may include the drill sharpness, the depth of the osteotomy, the amount of bone prepared, the variation in cortical thickness and the temperature and solution chemistry of the irrigant.

When the implant is substantially compressed against the bone, the interface between implant and bone has a greater area of repair. Self-tapping via implant itself, meaning the implant cuts the bone during placement, can result in greater bone remodeling/woven bone around the implant in initial healing compared to bone tapping before implant placement. The implant should not have any mobility on insertion; excess strain within the bone from torque and space filling may also increase risk of microdamage at the interface [33-35].

The recommended protocol for immediate load is to insert the implant with a torque of 45-60 Ncm [36-37]. This stability helps to ensure that the implant has a relatively rigid fixation in good quality bone. Additional torque may result in pressure necrosis and increase the strain magnitude at the interface and increase amount of damage and remodeling which could decrease strength of bone implant interface.

An alternate approach is to use a reverse torque test of 20Ncm to evaluate the quality of the bone and the interface at initial fixation for evaluating delayed healing. If the implant does not unthread at 20Ncm the resistance indicates that the bone is sufficient density to consider immediate loading.

Once the bone begins to receive occlusal loads by the implant restoration, the interface begins to remodel again. However, the trigger is strain transfer from occlusal function rather than trauma of implant placement. *Repair bone* is woven bone from surface trauma but *reactive woven bone is* woven bone formed from mechanical or loading response. The remodeling from mechanical strain can be called *bone turnover* and not only repairs damaged bone but also allows the implant interface to adapt to its biomechanical situation. The *interface remodeling rate* is the period of time for bone at the implant interface to be replaced with new bone [26].

*Strain* is the change in length of material/original length measured as % change [26]. The loaded bone next to an implant changes its shape, which is measured as strain. Microstrain conditions 100 times less than the ultimate strength of bone may trigger a cellular response. Bone fractures at strain levels of 1-2% but bone begins to disappear or form fibrous tissue, which is named the *pathologic overload zone* when strain levels of 20-40%. Therefore, the mechanical load is too severe, fibrous tissue may form at the implant interface

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rather than bone. Fibrous tissue at an implant interface may cause clinical mobility instead of rigid connection called osseointegration.

The ideal microstrain level for bone is the *adapted zone* and is called *ideal load bearing zone* [26]. The remodeling rate of bone in the jaws is in the physiologic zone of 40% of each year; the bone can remodel and remain an organized, mineralized, lamellar structure at these levels. The intermediate level of microstrain with the ideal load bearing zone and pathologic overload is called the *mild overload zone* [26]. In this strain region, bone begins its healing process to repair microfractures and the bone that is in a fatigue risk of failure. Bone in this range is reactive woven bone. Microstrain from overload or trauma causing accelerated bone repair causes less mineralized bone to form and less organized bone that is weaker [26].

Localized overload and possible implant failure might be possible due to excess stresses along the implant interface. However, immediate loading does not cause excessive stresses necessarily [26]. Initial response of bone at the implant interface has been evaluated on immediately loaded implants: direct bone-implant-contact with favorable bone quality around the implant has been reported. Brunski showed that a direct bone-implant interface may develop as long as the implant moves less than 100 μm and micromotion beyond 150 resulted in fibrous tissue encapsulation instead of a osseointegration [38]. Studies have shown that immediate loading of an implant interface did not increase risk of fibrous tissue formation. Long term results suggest that loaded implants have less marrow spaces and more compact bone. Greater direct bone contact was noted at the interface, suggesting that early occlusal loading may enhance bone remodeling and further increase bone density compared with unloaded implants [38].

Canullo et al., reported that the extension of bone remodeling was less extensive in cases of immediate placement (1.7mm) rather than delayed placement (3.0mm) [39]. Despite this limit in the healing zone, it has been shown that bone can fill osseous defects around implants if they are 3-walled in nature and <1.5-2.0mm wide. Other interventions such as autogenous bone grafts have been shown to be more osteogenic when used in conjunction with immediately placed implants. However, immediate placement does present some disadvantages. These can include unpredictable site morphology, a potentially limited amount of soft tissue, and risk of failure due to residual periosteal infection. Despite these potential disadvantages, immediate implant placement and immediate implant loading have shown to be favorable in maintaining or increasing bone heights around implants [1-4].

### 2.4. Biomechanical considerations

Any treatment plans involving immediate loading should have the goal to minimize the occlusal overload risk and its resultant increase in the remodeling rate of bone. The regional acceleratory phenomenon may replace the bone interface without the additional risk of biomechanical overload. The lower the stress applied to the bone, the lower the microstrain in the bone [26]. This provides conditions that increase the functional surface area to the implant bone interface. The surface area of load may be increased by variables including implant number, implant size, implant design, and body surface conditions. Force applied to the implant bone interface is related to the strain observed and some other factors such as patient conditions, implant position and direction of occlusal load.

Two approaches for immediate occlusal loading with edentulous patient include: over-engineering by placing more implants than the usual treatment plan for the conventional healing period; using selected implants around the arch (3+) to immediately restore with a transitional fixed prosthesis. In this approach, enough number of implants, which are needed to support a fixed prosthesis, are left submerged for the healing period. So, even if all immediately loaded implants fail, a fixed restoration can still be provided to the patient. If any immediately loaded implants survive, then they are also used in the final restoration [40]. This technique can be used where moderate to abundant bone is present in the posterior and anterior to the mental foramen. A study by Scortecci, involved loading all implants initially and splinting all for increased area of load transfer which could decrease stresses along the developing multiple interfaces and increases the stability, retention, and strength of transitional prosthesis during initial healing phase [41]. This technique allows you to use additional implants.

The functional surface area of occlusal load transfer along implant interface may be increased by increasing the implant number, especially when the devices are splinted through bridge-work. The biomechanical approach loads additional implants when immediate loading is planned. The lowest percentage of survival for a full arch restoration corresponded to a fewer number of loaded implants.

A rule in traditional prosthetics is that 3 pontics in the posterior of the mouth are contraindicated for a fixed prosthesis because of the amount of force and the flexibility and fatigue strength of the restoration [27]. When only 3 are used to support an immediate restoration there are often 3-4 pontics cantilevered. It has been suggested that additional implants should be placed with the staged healing approach in case one or more fails during the initial loading period. They can then be used in the final restoration to decrease the number of pontics and increase retention of final restoration

An increased number of implants reduces the risk of overload due to the increased implant surface area but also increases the retention of the restoration and decreases the number of pontics [27]. If fracture to a prosthesis or partially unretained restorations occur, the portion that is retained may act as a lever and overload the implants. The increased retention minimizes the occurrence of partially unretained restorations during healing which would be another source of overload to the implants supporting the restoration [27]. Decreases in pontic number also reduce the risk of fracture of the transitional restoration that could be a source of additional load to the remaining implants supporting the prosthesis. As a general rule, more implants should be inserted in maxilla to compensate for less dense bone and increased directions of force often found in the upper arch [27].

The most common number of implants used for a mandibular overdenture is 4-6 splinted in anterior mandible [5,24,42]. In a partially edentulous patient missing multiple teeth, ideally 1 implant should be placed for each missing tooth. For missing single teeth, the implant size, design or surface may be more important. Load may be reduced by reducing occlusal the contact and having a nonfunctional scheme.

The greater the benefit:risk ratio or the lower the risk, the more immediate loading should be considered. For example, a completely edentulous mandible restored with an overdenture

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supported by 4+ implants is a very low risk condition. If the patient can not tolerate a mandibular denture and does not wear it, the immediate load protocol would be a high benefit. An example of a high risk for immediate load would be posterior single tooth implant- the implant number can not be increased and you can not engage cortical bone; this would be of low benefit when out of the esthetic zone. Additional studies to evaluate risks especially in maxilla are expected [43].

### 2.5. Factors related to implant type/design

The area of load may also be increased by considering implant size, design, and surface. You can decrease stress by decreasing force applied to the prosthesis. These forces are influenced by patient factors, implant position, cantilever forces, occlusal load direction, occlusal contact positions, and diet.

Implant diameter and length are often emphasized in reports as these values give insight into the bone-to-implant surface area that an implant will provide. Avila et al., described that larger implants provided greater bone-to-implant contact and less susceptibility to cantilever forces following restoration [44]. More importantly, thread design and dimensions dictate the functional bone-to-implant surface area that will resist forces when a given implant is loaded along a given functional axis. Tapered implants offer a conical shape that is consistent with a natural root form but have less surface area which in turn results in increased crestal bone stresses and less primary stability.

For each 3mm increase in length beyond 10mm, you can increase the surface area by more than 20% for a cylinder implant design. Most stresses to an implant bone interface are concentrated at crestal bone. Therefore, increased implant length does little to decrease stress that occurs at the transosteal region around implant. But because immediately restored implant loads the interface before the establishment of a cellular connection, the implant length is more relevant especially in softer bone.

Benefits of increased length are found in the initial stability of the bone implant interface. Remodeling of the interface does not occur uniformly around implant- one region of interface remodels and other remains stable. Added length may allow remodeling in one region while other can stabilize implant. Added length can also allow implant to engage opposing cortical plate which can increase initial stability. Cortical bone has a lower remodeling rate and ensures stable condition during early loading. When trying to evaluate what length implant should be placed, it is important to consider that the survival rate of 10mm or less implants drops to less than 85% in traditional healing; Schnitman et al., found a 50% failure rate in immediately loaded implants with length of 10mm or less [45]. However, recent literature suggests that a high degree of survivability can be reproduced with implants that are at least 3mm in diameter and 8mm in length when splinted with other implants [46,47]. These findings, along with the innovations in implant design, suggest that these values should be revisited.

The functional surface area of each implant support system is related to the width and shape of the implant. Wider root form implants of the same length provide greater bone contact than narrower implants. Occlusal stresses are greatest in concentration at the crest of the ridge after the implant has integrated, so the width may be more important to the length of the implant to decrease the risk of crestal bone overload. Overload can cause early crestal bone loss in immediately loaded implants. The diameter of the implant increases in the molar area for immediate loading, especially when the density is less or the forces are greater. Increasing the width of the implant in molar sites or adding additional implants to increase the surface area in the posterior region can help alleviate overload that may result in crestal bone loss.

The implant body design needs to be more specific for immediate load because maximum stability is needed at the time of placement. After placement, bone has not had time to grow into the recesses or undercuts in the implant body or attach to the conditioned surface before occlusal load is applied. A threaded implant body and insertion process provides a better chance of stabilization. The implant design has a greater impact on the functional surface area than the implant size. The functional surface area is greater during immediate load, and a threaded implant presents many advantages over a pressfit type of implant for immediate load because the design features do not require integration to resist loads and have a greater surface area to resist occlusal forces [48].

The number, spacing, and orientation of the threads affect the amount of area available to resist the forces during immediate loading [49,50]. A greater number of threads means a greater functional surface area at the time of immediate load. The smaller the distance between threads, the greater the thread number corresponds to the surface area. Thread depth is also a variable to consider. Greater depth means a greater functional surf area for immediate load application. Functional surface area is more important when the number of implants cannot increase (less than 4 adjacent teeth are being replaced).

Thread geometry can affect the strength of early osseointegration and bone implant interface. A V- shaped thread design withstands a 10x greater shear force applied to bone compared to a square thread shape. Bone is strongest in compression and weakest in shear loading. Compressive force transfer would decrease microstrain to bone as compared to shear force. Therefore, a square thread design may provide a benefit in immediate load protocols.

The higher the remodeling rate of a loaded interface creates a higher woven bone ratio and weaker bone interface. A square threaded implant design with deeper threads has a 10x reduction in resorption rate. When considering a tapered implant design for immediate load, consider that this type of design allows for a less overall surface area compared to a straight design of the same length, width, and thread number. A tapered design will also have less thread depth near the apical portion of the implant, which reduces the surface area but decreases initial fixation. Thread depth and a tapered body can combine to improve initial stability, and may be a good option in lower density bone when less than 4 teeth are replaced and implant position and number can not be manipulated. Implant number, position and patient factors are more relevant to success and there have been few trials that compare immediate load with different implant thread designs and tapered implant bodies in the edentulous patient [50,51].

When the implant surface is modified with a roughened texture, this increases the bone to implant contact [52,53]. The shear strength of an implant with a roughened texture has been shown to be 5x greater than implants with smooth surface. The surface condition also affects the rate and percentage of bone contact, and lamellar bone formation. Surface coatings and conditions of the implant have been shown to be most beneficial during the initial healing and early loading conditions. For immediate loading, the most desirable surface is one that will allow the greatest percent of bone formation, has the highest bone-implant contact percentage with the highest mineralization rate, and the fastest lamellar bone formation.

A rough surface will initially increase stability; a machined surface is less successful to do so, especially in low density bone. A hydroxyapatite (HA) coating has been shown to decrease resorption rates during occlusal loading, which can increase the percentage of lamellar bone formation at the interface. If the bone is not an ideal density for immediate loading, the surface condition of the implant body may decrease the risk of occlusal overload. In summary, a rough surface provides a better condition than a machine surface; and in good quality bone, the types of surface condition is less relative to the overall implant survival [54].

Strain placed on the bone is influenced by the stress directed to the implant interface [26]. Ways that stress can be reduced include increasing the surface area that supports the occlusal load or by decreasing the force that is applied to the prosthesis. It has been recommended to not remove the prosthesis once it is delivered within first 2 weeks, and that resorbable sutures may be beneficial.

## 3. General considerations for treatment planning

Patient factors such as bruxism and clenching parafunction are forces that are high in magnitude, extensive in duration, and generate primarily horizontal forces to the implant. Parafunction presents a considerable risk and potential contraindication for immediate load due to this resulting in the poorest implant survival data [55]. There is an increased risk of abutment screw loosening, unretained prostheses, fracture of the transitional restoration used in immediate loading when a lever forms and increasing the risk of occlusal overload.

Implant position is an important factor for the edentulous patient. In the partially edentulous patient it is important to eliminate cantilevers on two implants supporting 3 teeth rather than position the implants next to each other with a cantilever. There will be less stress directed towards the implant interface when implants are not in a straight line in an edentulous site [24,36]. Cross-arch splinting is a very effective way to reduce stress within the entire implant support system, especially when there is an antero-posterior (AP) distance between the splinted implants. The splinted arch concept for the completely edentulous patient is advantageous for the immediate load transitional restoration. A line is drawn from the distal of each posterior implant. The distance from this line to the center of the most anterior implant is called the *anteroposterior distance* (A-P spread). The greater the A-P spread is between the center of the most anterior implant or implants and the most distal aspect of the posterior implants, the smaller is the resultant loads on the implant system from cantilevered forces because of the stabilizing effect of the A-P distance [27].

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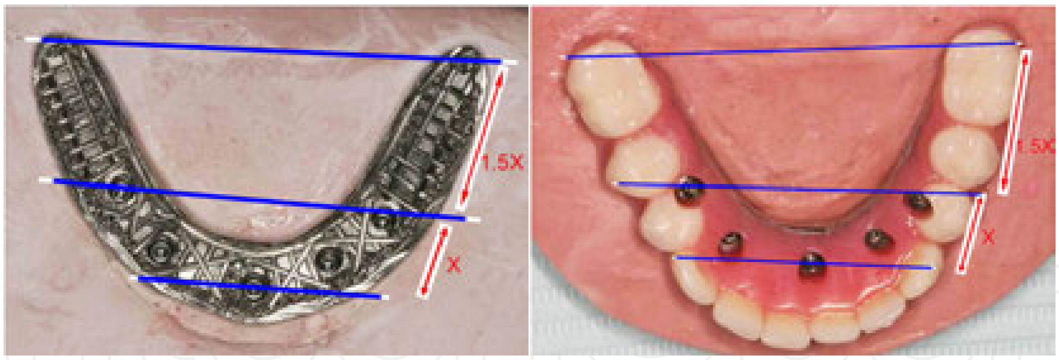


Figure 1: A-P spread and length of cantilever for framework (a) and final restoration (b).

**Figure 1.** A-P spread and length of cantilever for framework (a) and final restoration (b).

A square arch form involves smaller A-P spreads between splinted implants and should have shorter-length cantilevers. A tapered arch form has the largest distance between anterior and posterior implants and may have the longest cantilever design [27].

### 3.1. Treatment planning of mandible

The mandible should be divided into three sections when planning for implant placement: canine to canine; bilateral posterior. This is different from the maxilla, which needs more implant support because the bone is less dense and the direction of force is outside of the arch in all excursive movements; here you must consider the maxilla in at least 4 sections depending on the magnitude of force and the shape of the arch. These sections include the bilateral canine area and the bilateral posterior areas; at least 1 implant should be inserted into each section and splinted during immediate load for the completely edentulous patient.

Concerns about medial mandibular flexure with cross-arch splinting suggests that the final restoration should be fabricated in at least 2 sections when implants are placed in both posterior quadrants and fewer than 3 adjacent pontics are present [56]. The following photos show the restoration of an mandible with a 2-piece implant-supported fixed restoration.

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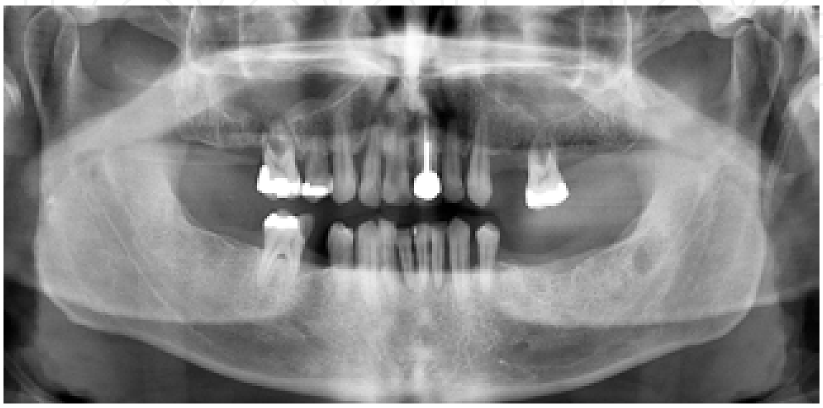

**Figure 2.** Panoramic radiograph of patient before treatment.

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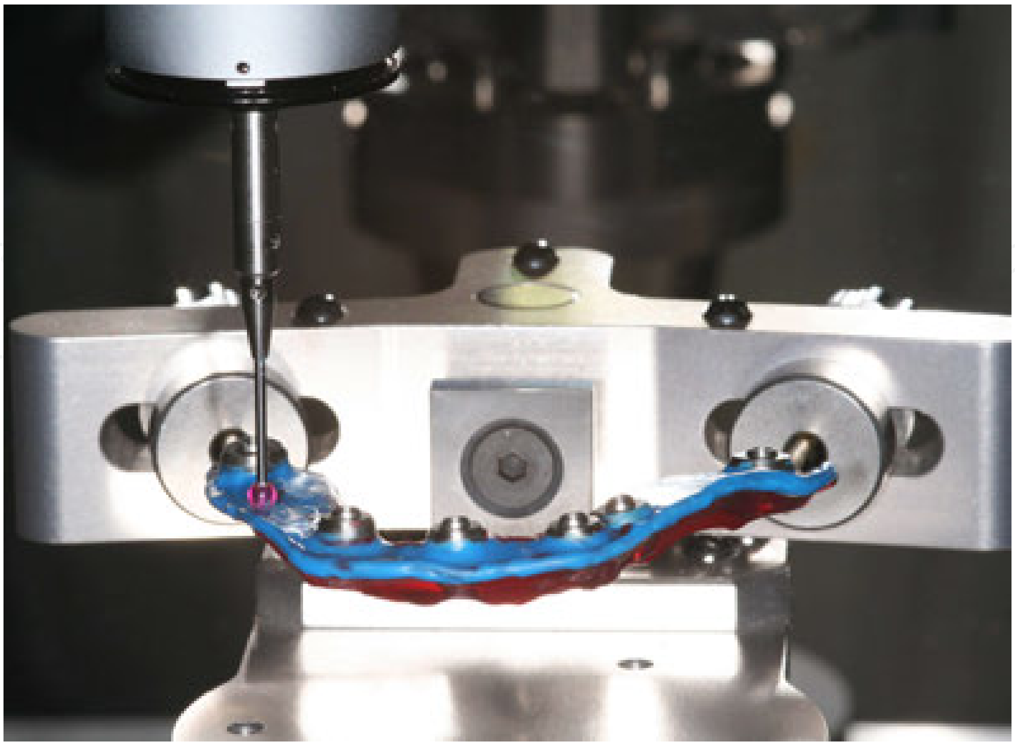

**Figure 3.** Scanning of tissue surface of mandibular wax pattern by using CAD/CAM.

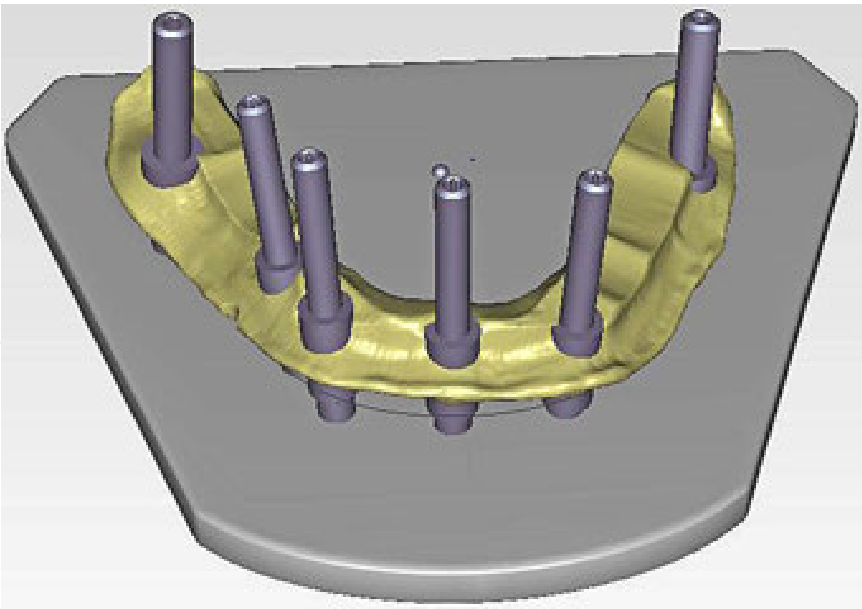

**Figure 4.** Final design of mandibular framework.

**Figure 5.** Clinical fit of mandibular framework verified after it was sectioned in two pieces.

**Figure 6.** Implant-supported screw-retained fixed dental prosthesis, in two pieces, was fabricated in the laboratory.

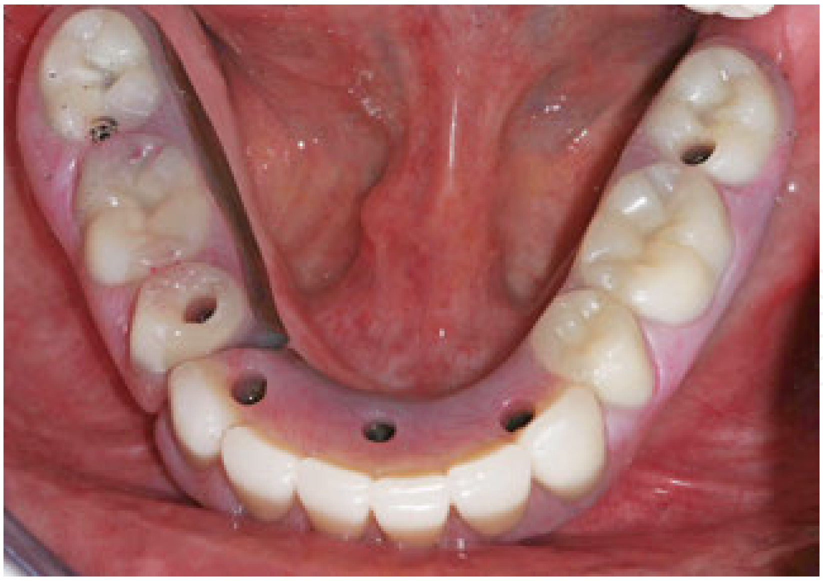

**Figure 7.** Occlusal view of mandibular implant- supported screw-retained fixed dental prosthesis at delivery.

**Figure 8.** Intra-oral view after inserting mandibular restoration.

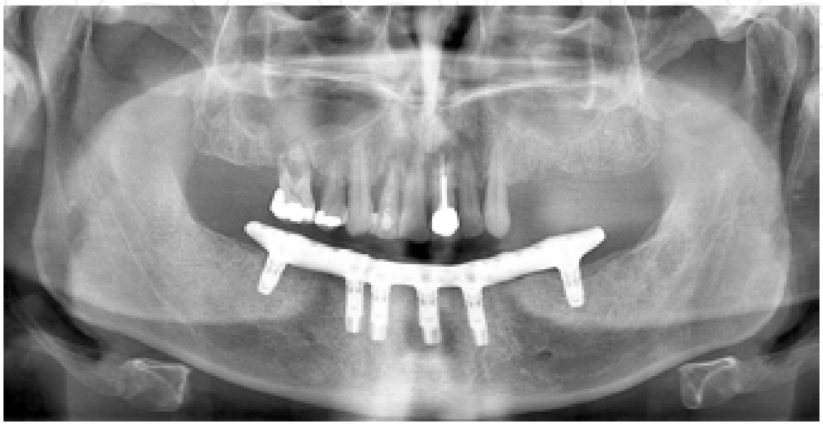

**Figure 9.** Panoramic radiograph at delivery.

**Figure 10.** Intra-oral view after inserting interim maxillary removable partial denture.

### 3.2. Factors influencing restorative plans

Cantilevers increase moment loads to implant bone interface and can increase the amount of crestal bone loss observed, increase abutment screw loosening, increased implant body fracture, and increase the risk of implant failure. The immediate load transitional should not have a posterior cantilever -not in esthetic zone- and bite forces are greater posteriorly; especially in the partially edentulous patients without a cross-arch support system. Partially uncemented restorations may result in a cantilever along the remaining implants; considering a definitive cement for transitional restoration to decrease the risk of partially retained restorations can be considered.

An occusal load direction along the implant interface may affect the resorption rate. Axial load has been shown to maintain the lamellar bone and has a lower resorption rate. The crown height can also serve as a vertical cantilever when angled forces or cantilevers placed. Flat occlusal planes in the posterior decrease risk of angled loads. The amount of force can be decreased by modifying the occlusal contacts so as to decrease or eliminate contact on the restoration. In the completely edentulous patient, parafunction may be eliminated by restoring with an immediate load overdenture and having the patient remove it at night. Having a stress relief attachment to implants can decrease the force transferred while the prosthesis is in function.

The patient's diet should also be a factor to consider and can lead to the fracture or loosening of the transitional due to overload. The patient should be instructed to eat only soft foods during the immediate loading period. The mechanical properties of bone should be considered as a less dense bone type has a lower strength. The bone-implant contact decreases for less dense bone, and the strength of the bone is directly related to its density, with the less dense bone type being weaker. The rate of resorption of dense cortical bone is slower than trabecular resorption rates; cortical bone is more likely to remain lamellar during the immediate load process than trabecular bone.

In summary, the greater number of implants, the greater length and width of implants, rough surfaces that provide greater surface area; placement of implants to maximize antero-posterior spread and decrease cantilevers should be considered in lower density bone types when planning for immediate load. The bone in the anterior is cortical bone at the crestal and apical areas; root forms implants should be placed to engage the opposing cortical plate when immediate load is contemplated to maximize primary stability and optimize mechanical conditions.

The posterior maxilla has a thin sinus floor and the mandibular canal location does not always allow engagement of the opposing cortex; the posterior maxilla is the area that caries the highest risk of implant failure when a 2 stage healing approach is used [57,58]. The implant number, width, and design are methods to decrease stresses to the interface in these regions. Use of conventional healing for type 3 or 4 bone quality when less than 10mm height exists. Bone grafting depends on many factors to be predictable: blood supply and lack of micro-movement [57-60]. Developing woven bone is at more risk of overload, and grafting is more predictable when soft tissue covers the graft and membranes are used. Immediately loaded implants should be placed in an existing bone volume that is adequate for both early load and that has the proper prosthetic design. Bone grafting before implant placement and then implant insertion and immediate loading after graft maturation is suggested when inadequate bone volume is present for proper reconstructive procedures.

### 3.3. Restoratively-driven treatment planning

Implant rehabilitation should always be prosthodontically driven [6]. This philosophy promotes a reduction in implant micromovement through appropriately positioned and loaded restorations. If restorations are inappropriately designed, a loss of osseointegration and/or prosthetic failure is more likely to occur. Axial implant loading is a desirable treatment goal since lateral forces greater than 30Ncm have been shown to produce micromotions greater than 100μm. Non-axial loading can also contribute to the loosening of abutment screws, a major cause of prosthodontic failure. Nordin et al., described that a high precision and passively fitting prosthesis reduced stresses and strains that could be detrimental to a healing implant [61]. In their study, they utilized the "Cresco Precision Method" to allow a high precision passive fit, intended to reduce stress and strain on the implant-bone interface during prosthetic fixation. Some researchers have implemented splinting and cross-arch stabilization on implants that are not loaded along their long axis. In an effort to avoid the maxillary sinus, Bevilacqua et al., placed distal implants in an angulated manner [62]. This technique has shown bone loss around the distal implants that is similar to more conventionally placed implants. Others have demonstrated 100% survivability using a similar concept called V-II-V, where 6 implants are placed into the maxilla at 30-45 degree angulations to the occlusal plane in the posterior maxilla to avoid the maxillary sinus.

Some researchers have reported that a similar prognosis could be expected whether or not the splinting of implants was utilized [63,64]. Especially when evaluating implant treatment in the maxilla, it is more common to find reports supporting reductions in micromovement and increases in overall survivability and success when splinting and cross-arch stabilization are used. Various combinations of prosthodontic materials are available, including: all-resin, metal reinforced resins and ceramics and all-ceramics. Literature describing the ability of each type of restoration to adequately splint immediately loaded implants to permit osseointegration suggests that stability, rather than the material used, is the critical factor. However, Collaert and De Bruyn reported resin fractures leading to prosthodontic failure and they subsequently altered their protocol to utilize metal reinforced fixed prostheses [65]. Nordin et al., reported failures of distal implants supporting all resin full-arch prostheses [61]. This failure is consistent with both Ibanez et al. [66], who reported that stability from splinting is the primary concern for success rather than other factors such as implant length, and Bergkvist et al.[67], who described impaired healing of implants under a removable prosthesis. Nordin et al., subsequently cited material thinness as the likely cause of inadequate rigidity, suggesting that if adequately thick, an all-resin fixed prosthesis would provide adequate splinting and cross-arch stabilization. Since implants are susceptible to overload with excessive micromotion and since they do not possess a periodontal ligament, pathologic bone strain and fibrotic healing are more likely to occur with poor occlusal management. An occlusal scheme that is perpendicular to the long axis of the implant, has freedom in centric relation, avoids cantilever forces, does not have interferences during excursive or protrusive movements and is in group function where possible also reduces non-axial forces on the implant and screw fixation components.

## 4. Conclusion

The more current reports suggest that the prevalence of implant survivability has increased and that previous recommendations may not reflect the survivability that current treatment planning and delivery options afford. Careful surgical preparation and performance, considerations in restoration design and maintenance, a regular recall regimen and good oral hygiene can predictably and consistently yield successful results. This has been proven continuously in the literature for the mandible. Although the maxilla has yet to prove itself in long term evidence based studies, the interim results of various investigations suggests that by carefully following guidelines and respecting the biology of the "softer" maxillary alveolar bone and the anatomic limitations of the upper jaw, clinicians may achieve long term success rates similar to those consistently realized in the mandible.

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