1. Introduction

The introduction of osseointegrated implants in dentistry symbolizes a turning point in clinical dental practice. Immediate loading (IL) of dental implants has recently gained popularity due to several factors including reduction in treatment time and trauma as well as aesthetic and psychological benefits to the patient. A fundamental prerequisite for implant success is substantial primary stability at the time of insertion and following loading of the implant. It may be considered as the unifying principle behind the need for adequate bone volume and density, longer or wider implants, and the 3-6-month delay recommended before implants are placed in function. A poor primary stability is one of the major causes of implant failure; other related causes of implant failure include inflammation, bone loss, and biomechanical overloading. An early detection of problems is essential and every effort should be made to
treat the problem while the damage can still be controlled or even overturned.

Although establishment of a good primary stability has been the primary focus during implant placement, there are numerous other factors that may contribute in providing an initial retention to the implant. Therefore, it is critical to maintain the integrity of the peri-implant tissues since bone resorption takes place with or without implant placement in the fresh extraction socket.5 However, research and understanding in this area is still unclear and results are sometimes confounding. Specifically, for immediately loaded implants, the role of the primary implant stability with the surrounding, mature bone seems to be crucial for the long-term success.5–8 Hence, in the present literature review, we aimed to assess and clarify the significance of primary stability during IL of dental implants.

### 1. The concept of immediate loading

Traditionally, endosseous implants are loaded once bone healing at the bone-implant interface has occurred. The complete healing phase may take up to 12 months following extraction.9,10 However, this post-extraction period may be accompanied by several problems such as alveolar bone resorption as well as psychological distress to the patient.

Today immediate loading (IL) of dental implants is an eminent and acknowledged treatment strategy which is extensively being used for the rehabilitation of missing teeth in healthy as well as medically compromised individuals.5 Primary IL may be described as functional loading (with occlusal contacts) immediately after implantation (or within 3–4 days after surgery) without waiting for the healing period.4 Primary IL has gained popularity due to less tissue trauma, reduced overall treatment time, decreased patient’s anxiety and discomfort, high patient acceptance and better function and aesthetics.14 In a clinical retrospective study, dental implants were loaded immediately after surgery in the area of the mental symphysis in 226 individuals.15 This study concluded that the success of immediately loaded implants is similar to that obtained in the case of delayed loading, once osseointegration has occurred.16 Studies based on histologic and histomorphometric evaluation of immediately loaded implants recovered from humans have also shown a high degree of bone-to-implant contact percentages.5

### 2. Objectives

The aim of the present literature review was to evaluate the role of primary stability for successful IL of dental implants. In this regard, the addressed focused question was: Is there a relationship between primary stability and successful IL of dental implants? Several factors influence primary stabilization of dental implants, therefore the pattern of the present review was customised to mainly summarize the pertinent information.

#### 2.1. Search strategy

As a first step, the authors (FJ and GER) searched the National Library of Medicine, Bethesda, Maryland (MEDLINE-PubMed) for appropriate articles addressing the focused question. Databases were searched from 1979 up to and including April 2010 using the following terms in different combinations: “immediate loading”, “dental implants”, “early loading”, “delayed loading”, “oral implants”, “immediate restoration”, “primary stability”, “initial stability”, “implant shape”, “implant design”, “bone mineral density”, “surgical technique” and “review”. This was supplemented by hand-searching in peer-reviewed journals and cross-referenced with the articles accessed. Any disagreement between the authors was resolved via discussion.

#### 2.2. Eligibility criteria

The following eligibility criteria were imposed:

- Clinical and animal studies.
- Intervention: immediate loading of dental implants.
- Reference list of potentially relevant research articles.
- Articles published only in English language.

Letters to the Editor, historical reviews and unpublished articles were not sought.

### 3. The role of primary implant stability

Osseointegration occurs in two levels: primary and secondary.18 Primary osseointegration is associated with the mechanical engagement of an implant with the surrounding bone after implant insertion; whereas bone regeneration and remodelling offers secondary osseointegration (biological stability) to the implant.18

Primary stability, defined as the biometric stability immediately after implant insertion, is a critical factor that determines the long-term success of dental implants.20 In other words, primary stability is the absence of mobility in the bone bed after the implant has been placed. The phenomenon behind this is the same as that applied for reduction of fractured long bones; that is, there should be utterly no movement between the fragments when the ends of a fractured long bone are reduced to endure fracture healing.21 This is because movements even at the micrometer range can induce a stress or strain that may hinder the formation of new cells in the gap. Likewise, during implant healing a micromotion between 50 and 150 μm may negatively influence osseointegration and bone remodelling by forming fibrous tissues at the bone-to-implant interface thereby inducing bone resorption.22

Several studies4,5,13,24–28 have reported high success rates with IL of dental implants, which are attributed to high primary stability. In some clinical studies29–31 an immobilization using splinting (cross-arch restorations or partial splinting) was necessary to increase the stability of the implants after surgery.

#### 4. Primary stability for immediate loading in single-tooth implants

#### 4.1. Immediate loading in healed sites

Clinical studies on IL in healed sites have reported positive outcomes in terms of implant survival, marginal bone
resorption, soft tissue levels, the incidence of complications of treatment. Several studies have reported a success rate with positive tissue response. In this study, the mean change in marginal bone level was 0.01 mm at 12 months interval reflecting the presence of sufficient primary stability. Several studies have reported a success rate of 100% for IL in healed sites compared to implants in fresh extraction sites.13

4.2. Immediate loading at the time of extraction (fresh extraction sites)

There is adequate data to verify the fact that placing implants immediately after extraction is an alternative to implant placement after socket healing. It is mandatory for such implants to have an implant stability similar to that when placed in healed sites. Studies on animal models have also shown that the dimensions of peri-implant soft tissues remain within the biological range and are not negatively influenced by IL. Mijiritsky et al. investigated the long-term survival of single-tooth implants immediately placed in fresh extraction sites with a 6-year follow-up. In this study, 24 implants were placed in fresh extraction sites in 16 patients. The results demonstrated an overall implant survival rate of 95.8%. The study concluded that successful osseointegration can be accomplished with IL implants in fresh extraction sites. The peri-implant conditions were also stable till the sixth year of follow-up. Likewise, Degidi et al. evaluated the long-term survival of 111 immediate implants placed in 111 individuals with immediate provisionalization (out of occlusion) and monitored them over a period of 5 years. The parameters for overall success rate were defined by bone resorption of less than 1.5 mm after the first year of IL and less than 0.2 mm subsequently. The study reported a success rate of 92.5% for immediately loaded implants placed immediately after extraction compared to IL at healed sites (success rate: 100%). Barone et al. placed 18 immediately restored implants placed in fresh extraction sockets in 18 subjects. During the 1-year follow-up of individuals participating in this study, 17 of the 18 immediate implants remained successful under function. One implant was lost due to abscission formation and the overall implant survival rate was reported to be 94.5%. However, other studies have reported that the success rate of IL of dental implants in fresh extraction sockets is comparable to IL in healed sites. A recent study investigated the outcome of IL in extraction sites affected by periradicular lesions, such as fistulas and suppuration. In this study, the test group included 15 patients with periapical lesions or radiolucencies (such as fistulas or suppuration); whereas the control group included 15 patients without periradicular lesions but with root caries or root fractures. The 2-year follow-up results showed that IL in extraction sites affected by periradicular lesion, osseointegrated successfully revealing a positive outcome. Similarly, in a prospective clinical study, immediate implants were placed in 13 patients after tooth extraction and 11 patients received implants after complete socket healing. All implants were placed in the aesthetic zone and emphasis was considered on obtaining primary stability by achieving bicoortical anchorage and maximum insertion torque of at least 40 Ncm. Within the follow-up period between 1 month and 15 months, all the 24 fixtures showed functional stability. The success rate for both the immediate implant and implants placed at healed extraction sites was 100%. Lorenzoni et al. treated nine patients using an IL protocol. None of implants failed up to 1 year after insertion, resulting in a survival rate of 100%. Similar results were reported in other studies, where IL of single-tooth implants placed in fresh extraction sockets was suggested as a valuable alternative to replace a missing tooth.

In contrast, a comparative study by Chaushu et al. reported data for IL, where 19 implants were installed in fresh extraction sites and nine implants were placed in healed sites. After a follow-up period ranging from 6 to 24 months, the survival rates for immediate implants versus implants placed after healing were 82.4% and 100% correspondingly. The study concluded that IL in fresh extraction sites carries a failure risk of approximately 20% whereas IL in healed sites is a more promising treatment alternative. The success rate of IL in fresh extraction sites has been reported to range between 79 and 85.7%. These results are summarized in Fig. 1.

5. Implant design and surface characteristics in relation to immediate loading

Implant design, a vital parameter for attaining primary stability, refers to the three-dimensional structure of an implant with all the components and features that characterize it. Implants of varying designs reach various degrees of stability, which may determine their future clinical performance. The screw or “threaded” design minimizes the implants’ micromotion during function thereby maintaining the primary stability. Furthermore, a threaded design also increases the surface area of the implant thereby offering a higher percentage of bone-to-implant contacts, in comparison to implants with a cylindrical design. Therefore, threaded type implants are generally recommended and particularly for IL. The Vandamme study also showed that threaded implants offer significant bone-to-implant contact during (compared to cylinder-shaped implants), which may also enhance the secondary stability. It is accepted that all implants display some extent of bone loss after osseointegration and through time of function. It has been claimed that the introduction of microthreads or “retention grooves” at the neck of the implant may also assist in reducing distributing stress and reducing the extent of bone loss following the implant installation. Hence, cylinder-type implants seem to be contraindicated for IL regimes due to lowering of primary stability and less resistance to vertical movement and shear stress. However, according to the Chong study, if bone quality and quantity are optimal, then they may compensate for implant design inadequacy.

Tapered implants were initially designed mainly to serve for IL after tooth extraction. The theory behind the use of tapered implants is to provide for a degree of compression of
the cortical bone in a poor bone implant site. Cylindrical wide body implants increase the risk of labial perforation due to buccal concavities; whereas the decrease in diameter of the tapered implants toward the apical region accommodates for the labial concavity. In a study, tapered titanium implants (with lengths and diameters ranging between 3.3 and 5.5 mm and 13–16 mm respectively) were placed in 16 individuals. After a mean follow-up duration of 40.7 months, the overall implant survival rate was reported to be 95.8%.

Implant surface characteristics have also been shown to influence osseointegration. Studies have shown that surface topography and roughness positively influence the healing process by promoting favourable cellular responses and cell surface interactions. Rough surfaces are considered to enhance primary stability as they present a larger surface area and allow a firmer mechanical link to the surrounding tissues. Studies have reported that the type of loading contributes to the provision of high torque resistance after healing in implants placed in the posterior region of the mandible. A primate study demonstrated that implants treated with sandblasted surface and a progressive thread design can achieve osseointegration when immediately loaded. In these studies, the role of the progressive thread design has been emphasized. In vitro studies have shown that sandblasted implant surfaces promote peri-implant osteogenesis by enhancing the proliferation and metabolic activity of osteoblasts. In poor bone quality sites, implants with an acid-etched surfaces can achieve a significantly higher bone-to-implant contact compared to implants with a machined surface. In a study by Ibáñez et al., full arch restoration was provided to 41 individuals with 343 double acid-etched surface implants (bruxers and smokers were also included). The success rate was reported as 99.42% and the study concluded that a high success rate with IL can be obtained using double acid-etched surface implants. In another study, 405 implants with micro-textured acid-etched surface were consecutively installed in 11 completely and 16 partially edentulous individuals. The 3-year follow-up results showed a cumulative success rate of 97.5% for the mandible and 98.4% for the maxilla. IL with hydroxyapatite-coated implants has also shown constancy in implant stability and peri-implant tissue conditions when compared to conventional delayed loaded implants.

**6. Immediate loading with reference to bone density and quality**

Variations in bone density can occur in all locations in the oral cavity. Bone quality is often referred to as the amount of cortical and cancellous bone in which the recipient socket is drilled. For example, the densest bone is frequently located in the anterior mandible, followed by premaxilla and the posterior mandible. The least dense bone is usually present in the posterior maxilla as well as mandible. In this context, the clinicians should confirm their assumptions regarding bone density at the time of osteotomy development, since bone density at an implant site is a significant feature with respect to surgical protocol and osseointegration. According to Romanos et al., implant stability in the long-term after IL seems to be increased due to the significant increase of the peri-implant bone density at the implant–bone interface.

A poor bone quantity and quality have been indicated as the main risk factors for implant failure as it may be associated with excessive bone resorption and impairment in the healing process compared with higher density bone. According to Misch, most of the immediately loaded implants are placed in anatomical sites with dense and good quality bone. The mandible (particularly in the interforaminal region) has a better bone quality compared to the maxilla and this is probably the reason why reports are available regarding IL in the anterior part of the mandible with high survival rates. A histological study based on animal models, reported comparable bone quality values around implants placed in the posterior regions of mandible, following delayed as well as IL protocols. In a human split mouth designed study, it has been
concluded a high success rate (100%) of immediately loaded implants in a similar way like delayed loaded implants. In general, the use of IL in the anterior region of the mandible seems to play a significant role in the overall success since this region has the best bone quality. Clinical studies have reported dental implants in the mandible to have higher survival rates compared to those in the maxilla, especially for the posterior maxilla. In another study, immediately loaded implants in the anterior maxilla showed successful osseointegration (96.66%) with stable peri-implant conditions till at least the sixth year of follow-up. Cross-arch restorations on immediately loaded implants placed in the maxilla presented high success rates (96.66% after 6 years of loading), when the implants have a design allowing high implant primary stability. Results by Rocci et al. have reported a successful IL in the posterior maxilla (Fig. 2).

7. Impact of surgical technique on the primary stability

Besides the quantity and quality of bone and morphology of the implant, the surgical technique adopted also influences primary stability during IL. Surgical principles used to obtain a successful IL focus on two primary factors, atraumatic surgery and establishing rigid, initial stability. An atraumatic surgical technique is essential to maintain cellular viability thereby preventing the formation of an epithelial connective tissue layer along the bone–implant interface and promote healing. Thus, if proper surgical techniques are applied, then the clinical outcomes of IL can be superior to those for conventional delayed loading protocols. Likewise, IL with flapless surgery technique has also been shown to reduce the treatment period and enhance implant stability compared to the conventional flap surgery protocol. According to Oh et al., a flapless implant surgery provides esthetic soft tissue results in single-tooth implants either immediately or delayed loaded. Some studies have also preferred insertion torque as a determinant of implant stability and torque values of 32, 35, 40 N cm and higher have been chosen as thresholds for IL.

The use of computed tomography for a three-dimensional evaluation of bone implant sites is an interactive method for treatment planning and the fabrication of stereolithographic models as custom surgical templates. It has been documented that the use of stereolithographic appliances in accordance with flapless surgery assists in the IL of implants.

The bone condensing technique has also been suggested to enhance the primary stability of dental implants by increasing the bone density. Experimental studies have shown that bone condensing increases the bone-to-implant contact in early phases of implant placement. However, on clinical grounds, controversial results have been observed concerning the efficacy of this surgical method. Several studies have suggested against tapping and/or using osteotome techniques on recipient sites with poor quality bone. Gulsahi et al. placed single-tooth dental implants by both conventional and bone condensing techniques in 14 patients with bilateral missing teeth. The results showed no significant difference in bone mineral density and bone mineral content between the two implant placement techniques. Interestingly, the success rate of the conventional technique (92.9%) was greater than the bone-condensing technique (71.5%). Experimental studies have shown that bone condensing can lead to fractured spongiosal trabeculae. In another study, 22 implants were inserted using the bone condensing technique and the labial cortical plate fractured in three patients during the procedure. On the contrary, some clinical studies have shown that bone condensing yields an improved histologic bone-to-implant contact.

IL using cross-arch fixed restorations has been shown to enhance implant primary stability. In a study by Romanos and Nentwig, implants were connected with their abutments and splinted immediately after surgery using cross-arch fixed temporary restorations. After a mean loading period of approximately 3 years, good implant stability without bone loss was observed. The results demonstrated a long-term success (98.6%) of IL implants placed in occlusal function using fixed cross-arch implant-supported restorations.
8. Methods of evaluation of the primary stability of the immediately loaded dental implants

Stabilization of IL implants in the surrounding lamellar bone has been standardized using a variety of techniques including the periotest, resonance frequency analysis (RFA) and cutting torque resistance analysis.

8.1. Periotest

The periotest has been supported as a reliable method to gauge primary stability.\textsuperscript{24,95} It is composed of a metallic tapping rod in a handpiece, which is electromagnetically driven and electronically controlled. Signals produced by tapping are converted to unique values called “periotest values”. Periotest has been shown to be helpful in determining the implant stability not only in conventional implants but also in IL of dental implants.\textsuperscript{5,96} According to Dilek et al.\textsuperscript{96} IL can only occur if their periotest values in between the range of –8 to +9. Results by Abboud et al.\textsuperscript{38} also reported that periotest values of “-4” to “+2” are indicative of a successful IL protocol. However, other studies have given even a narrower range for periotest values, that is –4 to –2 and –4 to +2.\textsuperscript{97}

8.2. Resonance frequency analysis (RFA)

RFA can be used to monitor the changes in stiffness and stability at the implant–tissue interface and to discriminate between successful implants and clinical failures.\textsuperscript{4,56,99} which was replaced by the “implant stability quotient (ISQ)” introduced by Ostell (Integration diagnostics).\textsuperscript{5,40,99} However, it is tricky to characterize a general standardized range of ISQ readings for a successful implant osseointegration for different implant systems.\textsuperscript{100}

In a recent study, Zix et al.\textsuperscript{98} compared two non-invasive methods used to measure dental implant stability, such as Periotest and RFA (Ostell). The results showed that both measurement techniques had a significant association to the implant diameter; however, the RFA technique appeared to be more precise compared to the periotest.\textsuperscript{98} In another study, Sjöström et al.\textsuperscript{99} compared implants placed in grafted and normal non-grafted maxillae by means of RFA. In this study, the RFA for failed implants showed lower values compared to successful implants. Experimental studies\textsuperscript{100,101} have also investigated the hypothesis that measurements of implant stability using RFA correlates with histomorphometric data of bone anchorage. However, the results could not verify the hypothesis since that RFA values at the time of implant placement did not correlate with the torque required to tap the bone for implant placement. The study concluded that validity of the individual measurement of implant stability using RFA should be considered with caution.\textsuperscript{101} The results of the clinical studies should be evaluated with caution, because the boundary height, width, and density factors can influence the resonance frequency of dental implants.\textsuperscript{102}

However, there is no clinical study today, which proves the RFA level for implants, which survived in a long-term and the necessary minimum RFA threshold we need for the success of IL implants.

8.3. Cutting torque resistance analysis

In the cutting torque resistance analysis (CRA), the energy required for an electric motor to cut bone during implant surgery is measured. This energy was shown to be significantly associated with bone density which influences primary stability.\textsuperscript{103} CRA may be used to determine bone hardness and also to locate areas of low bone density. A torque gauge incorporated within the drill is used to determine the insertion torque. According to O’Sullivan et al.,\textsuperscript{104} there is a significant difference in CRA between type-1 and type-4 bone types. Major limitation of this technique is that it does not provide any information regarding bone quality until an osteotomy is performed.

9. Conclusion

There is a significant biological response by the hard and soft tissues to IL of dental implants. Within the limitations of the present literature review, it is evident that the core issue to observe during IL is the establishment of a good implant primary stability. There is sufficient evidence to suggest that the degree of achieved primary stability during IL protocols is dependent on several factors including bone density and quality, implant shape, design and surface characteristics and surgical technique. Further research is required in situations, such as poor bone quality and quantity and multiple implants or augmentation procedures, which may challenge the attainment of primary stability during IL.

Conflicts of interest

The authors declare that they have no conflicts of interest and there was no external source of funding for the present study.

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