Significance of Splinted and Non-splinted Implant Design and Stress Distribution Analysis: A Review

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Abstract. The aim of this review article is to evaluate the distribution of the stress in and around the implant. The implants used are short implants with either splinted or non-splinted and are fixed in the mandible or maxilla. This study majorly focuses on in-vivo and in-vitro study. An intense literature review was done of many review and research articles comparing the effect and success rate of splinted and non-splinted dental implants with varying crown-to-implant ratios. Short implants of 6mm length and 4.5 mm diameter were studied based on application and FEA analysis examination for different loading conditions carried out in various research articles. The crown-to-implant height doesn’t affect much while loading axially but the generated displacement and stress concentration factor when obliquely loaded. The splinted and non-splinted have their own set of limitations, although research suggests that splinted restorations have less technical concerns.

1. Introduction

The periodontal ligament essentially connects the tooth to the surrounding alveolar bone in the case of teeth, whereas implant osseointegration, which is an intimate contact between alveolar bone and implant surface without the interposition of fibrous tissue around the implants, is what ensures a stable and long-term connection in the case of dental implants [1]. Because dental implants are subjected to repetitive loading because of mastication pressures, it is important to investigate their fatigue life. This fatigue life is determined by the implant's size and composition, as well as the physical characteristics of the bone.

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The dependability and stability of the implant-bone contact and implant–abutment connection are critical for a dental implant's long-term success [2, 3]. The mini and short dental implants since past years have grown into popularity as these dental implants have come up as reliable possible treatment for restoration of one-tooth or multiple-implants in edentulous patients [4], with substantial success rates in restoring the biting function and appearance. Maintenance of live bone tissue around the implants positioned in the atrophic maxillary posterior areas is still regarded as a considerably difficult [5]. The implant architecture has progressed in tandem with implant therapy and have become a pivotal moment in the rehabilitation of patients who are partially or completely edentulous. Commercially accessible implant thread profiles come in a variety of sizes and shapes. Understanding that for effective recovery, the thread profile on stress distribution to the surrounding bone is important [6, 7]. The use of standard long implants is always not possible as the amount of accessible bone tissue in this location is inadequate to support them. Thus, methods such as the rising the level of the maxillary sinus or usage of implants with small height have been implemented despite these anatomical idiosyncrasies in order to allow an implant rehabilitation. However, the surgery is linked to an increased risk of surgical complications, morbidity, and treatment costs [8]. Therefore, finite bone quality leads to consideration of small implants which are said to be a simple and effective alternative. In previous years, short implants are associated with lower survival rates [9]. The short implants in the posterior maxilla or mandible have worse survival rate for a variety of reasons. The main reasons are; compared to longer implants, they have less bone to impact region as implant surface is less. Short implants are placed in the region having poor alveolar bone quality, especially in the maxilla [10]. Small implants also lead to oversized crowns to meet occlusion thereby raising the ratio of crown-implant and resulting to deprivation of bone and eventually failure of implant. The review assesses the stress dispersal on implant-abutment and live tissues in the bone which is fixed and supported by prosthesis using splinted and non-splinted crowns with various crown-to-abutment ratios, such that crowns of splinted and non-splinted have equivalent stress distributions around implant supports and jawbone tissue, and that there remain less variations of stress dispersal amongst the implant lengths.

2. Implant Systems

2.1 Splinted Dental Implants

Dental splinting is a method used to settle and support the crown embed by joining at least two inserts into unbending unit through fixed or removable rebuilding efforts to stay away
from extreme versatility which can cause distress during masticatory activity [12]. Implants as of now make an unbending framework, making the reclamations more inclined to ceramic fracture, so the fundamental motivation to support them is better disperse the occlusal loads between inserts, limit the exchange of even burden deep down implant interface, and increment the bone surface region [13]. Supporting can be a benefit when nearby implants fizzle [14]. On the off chance that various adjoining inserts are supported, prosthetic reproduction of the implant scaffold should be possible on the off chance that at least one inserts fall flat [15]. This is a more non-obtrusive methodology than eliminating then whole prosthesis and manufacture another one [16]. Supported inserts are likewise thought about when implant reclamation position isn't ideal to stay away from lopsided force application on inserts [17].

2.2 Non-splinted Dental Implants

Non-splinted dental implant is contrary to splinted dental implants. Dental implant restoration is usually non-splinted when it is not to be loaded immediately and the early previsualization period is less than 6 weeks [12]. Even when the dental implants are not in a cantilever position non-splinted implants are used as the masticatory forces are significantly reduced [17]. The benefit of non-braced inserts as far as keeping up with appropriate cleanliness by the patient is very clear when contrasted and a poorly planned supported rebuilding [18], one that gives practically zero admittance to performing cleanliness techniques at home [14]. Interproximal access is a conspicuous factor that rapidly rings a bell for example. Nonetheless, comprehend that a very much planned braced reclamation with proper access for cleanliness ought not have any impact on peri-implant wellbeing [19]. Non-splinted reclamations will in general throw a tantrum and as the quantity of implants inside the rebuilding increments, as does the capacity of accomplishing latent fit [20]. This sort of dental inserts is suggested for patients with diminished manual aptitude, helpless oral cleanliness [21, 22]. A search of the literature for publications comparing the success of splinted with non-splinted dental implants was conducted. The tree a comprehensive approach towards selecting an implant.

![Flowchart for selection of splinted or unsplinted implant](image)

**Figure 2.** A flowchart for selection of splinted or unsplinted implant [12]

3. FEA Study

One of the most frequent and helpful numerical methods for obtaining an accurate stress distribution field around the bone-implant contact is finite element analysis (FEA) [23]. It is largely utilised to forecast the mechanical behaviour of dental implants as well as the variables that impact implant behaviour [24, 25]. From a mechanical perspective, FEM
modelling confirms the idea that splinting diminishes harm advancement in the bone tissue, which is consistent with the clinical investigation [26].

The implants were modelled as cylinders and fixed-boundary portion of the maxilla was incorporated [26] were constrained in x, y, z direction replicating fixation of upper jawbone and a cement connection was used to imitate implant-support crowns of 49.92 µm with application of axial 400N, 49.97 Newton on interior slope and 200.1 N diagonally [8]. The stress levels in the maxilla produced by biting force loads were investigated in this study utilising the FEM software TRINITAS [26]. The findings were in line with earlier research, which shown the splinted crowns enhance stress distribution with neighbouring tooth in other implant connections. Benefit of splinting of crowns in dividing stress with supplementary implants is due to the strong union of components, which allows for stress distribution amongst implants [27]. The non-splinted crowns displayed higher stress convergence under axial loading on the mesial of the first grinder abutment, while splinted heads on other hand dissipate tension between inserts reducing pressure in mesial nevertheless raising stress in the distal abutment of the first molar in Von Misses Stress. Whereas when axial loading was compared to oblique loading, there was reduced ductile stress on the cortical mandible muscle, especially on foremost molar area. When equated to non-splinted crowns, splinted heads caused pressure spreading by lowering malleable stress on primary molar area; nevertheless, small rise of workable stress in following bicuspid province was detected [8].

According to a mechanical perspective, splinting is probably going to emphatically influence mending after a medical procedure [26]. Burak Yilmaz in his research paper found that both the patterns were of strain distribution were somewhat similar for both splinted and non-splinted crowns under vertical and oblique loading. It was concluded that splinting does not significantly affect strains distributed to bone when cemented retention is used[28]. Furthermore, splinting implants are designed to decrease the amount of force given to a single implant in order to avoid occlusal forces that are far too great [29].

If binary implantations which stood in succeeding bicuspid and molar sections of mandibular prototype. After that, the inserts were splinted with a 2-unit static bridge, and stresses were analysed using FEA. The ratios displayed straight relationship peri-implant maxilla stress, but total elevation of medical crown had added considerable significance. The transplant span has a smaller amount impact on peri implant jawbone pressure than insert width. Minor stresses were spotted in wide-width inserts even in set-ups concerning lengthy crowns. The conclusion made from this paper was that the crown elevation is an added central factor distressing the peri-implant bone pressure than C/I proportion used for splinted insert braced crowns. 2-unit secure restorations with bigger C/I ratio might be positively implemented in wide-span transplants in latter jawbone [30]. Although the majority of finite element analysis investigations revealed that splinted implants deliver small force to the insert figures, reducing the pressures imparted in the direction of the inserts, implant components, and neighbouring mandible muscle [12].

Whereas 2 groups were made having each of non-splinted and splinted implant. Oblique forces were simulated in molar with magnitude of 364.9 N and premolars with 200.1 N magnitude, the results found from this study were that the splinted prosthesis decreased the stress to the surrounding bone of short implants as well as the stress in the surrounding bone adjacent to the tooth. The splinted prosthesis however generated higher stress in the coverage of surrounding bone for regular intermediate implants. The conclusion that was drawn was
that the benefits of using splinted implants are significant for bone preservation surrounding short implant tooth [31]. Biomechanical behaviour of splined and non-splinted transplants in the posterior jawbone was compared, it was found that splinting the short implants produced reduced bone strain and stress, especially under diagonal forces. It was also found out that increasing the diameter also effectively contributed to reduction of strain but showed no significant changes in stress for axial and oblique loading [32].

![Figure 3. Distribution of stress levels with force of 300N at 10° slope diagonally from the rear and its splinted [26]](image3)

![Figure 4. (a) Acrylic block model with implant prosthesis (b) Fringe pattern observed under monochromatic light [6]](image4)
4. Discussion

While setting, this review planned to think about the bone stress created by Morse taper inserts by means of ordinary and small dimensions and splinted or non-splinted model. Most finite element examination studies showed splinted implants to circulate less force to the implant bodies, which diminishes the burdens moved to inserts, implant parts, and the encompassing bone tissue. In a photo elasticity study by Dhatrak et al as shown in Fig.4, compared the load distribution along bone-implant interface for selected five types of implant systems and testified for a more even load distribution at that region. One concentrate likewise announced that feelings of anxiety in bone tissue encompassing braced inserts were particularly lower than feelings of anxiety encompassing un-coupled implants by a factor of almost 9.27. Taking this in thought Clelland et al. detailed that splinted crowns didn't display huge divergences when compared and the non-splinted implants; in any case, splinted tops added to more even dissemination of pressures [2, 27]. Hence, indications for non-splinted cemented crowns under Morse taper implants are additionally practical because of simple access in the interproximal region, empowering better cleanliness and patient adaption, which thusly emphatically add to work on the personal satisfaction. The thing is obvious that bracing as referred to following author [11] is suggested for recovery in the subsequent area of the arch to stay away from hazard factors, forfeiture of crestal bone, and potential cracks of parts and fastens.

For a particular implant, because of the varied geometries and mechanical characteristics of the mandibular and maxillary molar segments, stress distributions at the bone-implant interface were distinct, resulting in a greater compressive overloading risk in the maxillary segment [33]. Small inserts in medical exercise have generally been seen as consuming minor endurance rates when contrasted with implants of standard lengths [12]. Their application practically speaking has been transcendently restricted to atrophic jaw circumstances or in direct situations to keep away from complex surgeries [13]. In the present writing, no immediate connection has been set up to occur amid insert dimension and its effect on insert endurance. Indeed, transplant dimensions lengthier than 9.98 mm don't exhibit a significant clinical benefit; and analysts have shown that the force disseminated about an insert, in capacity, are additional in the crestal section [14]. Nevertheless, it is accounted for that insert thickness assumes additional considerable part in energy dispersal than transplant measurement. [15] Shorter inserts bring about a higher C/I proportion by and large [34, 35] influence of insert dimension on insert endurance was assessed in many investigations [36, 37]. A generally large number of published examinations demonstrated an expanded disappointment rate related utilizing machined-surfaced implantations, and the arrangement in locales with helpless jawbone concentration [38]. Endurance of short implants has worked on in the course of the most recent couple of years [39, 40]. Ongoing publications detailing the utilization of textured-surfaced implants have demonstrated endurance paces of short implants equivalent with those acquired with longer ones, particularly in the mandible [41]. Most forces applied to the Osseo integrated implant body are gathered in the crestal bone, paying little heed to implant design plan and bone density [14].

A significant angle to remember when making inferences from these surveys is that small inserts are typically positioned in a non-perfect/conceded dental circumstance instead of the ideal conditions [42] where standard length implants are set [43]. Alongside this current significant inclination, other bewildering boundaries, for example, insert surface, diameter, implant location, mandible value, stacking conventions, prosthetic constructions, development stages, and techniques for statistical investigations, moreover, styling it an ill-advised correlation with make significant inferences. These boundaries are significant and fundamentally applicable when considering implant success [12, 44].
Summary and Future Scope

As per the information acquired from 3D FEA inspected in this research and in view of the investigations reported in the writing, the accompanying ends can be derived. The advantages in utilizing splinted prostheses is lessening of pressure to the encompassing maxilla of small inserts and decrease of jawbone pressure for the encompassing teeth [45, 46]. In any case, the burdens in utilizing supported prostheses are higher stress in the inclusion of the encompassing mandible of standard false teeth contrasted and the non-splinted prostheses groups [8]. It can be proposed that when utilizing ordinary and short implants in a similar setting, the association of the prostheses should be assessed to abstain from harming the bone encompassing the normal implants [47]. Non-splinted restorations will in general throw a tantrum and as the quantity of inserts inside the rebuilding increments, as per the capacity of accomplishing uninvolved fit. Splinted false tooth are probably going to have fewer specialized inconveniences in the long haul [48].

The extreme intensity of stress is at the proximal segment for the crosswise and slanting payload situations, while for perpendicular occlusal payload it is most likely seen in distal region of the crossing point [49]. The slanting load (masticatory force) incites more prominent pressure at the boundary as contrasted and perpendicular (occlusal load) along with crosswise payload situations. Forces are more focused close to the edge. Moreover, the extent of pressure magnitude diminishes towards the external section (away from inter-face).

The thread shape of the implant is the basic boundaries to adequately convey the force concentration and keep away from increased pressure accumulation at cancellated bone close to the edge [50]. Nonetheless, an expansion in insert measurement reduced pressure inclinations at cancellous peri-implant section [51]. Crestal mandible geometries described by low degrees of jawbone misfortune and clinically connected through stage exchanging arrangements showed compelling stress-based execution [52], bringing about a decrease in the danger of over-loading at the implant neck concerning initiated cratering of bone [1].

Accordingly, concluding up this survey the splinted implant was seen to be more productive and successful than non-splinted implant. Anyway, non-splinted implant has their own advantages and hindrances [53]. Contingent upon the length of the implant, the design plan boundaries can be iterated to accomplish plausible plan contemplations [54]. Nevertheless, noticing this trademark peri-implant bone levels around splinted and non-splinted implant were not genuinely unique for implants more noteworthy than 6 mm long; while non-splinted 6-mm inserts when contrasted with benchmark, shown a development in bone following two and three years, giving unrivalled iterative information [32]. The scarcity of data on this subject, additional research using a randomised controlled clinical trial design is required to achieve more conclusive results. Future studies should, in the end, be planned with more homogenous samples in terms of implant design (macro topography, thread design) and kind of connection.

References


