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Fixture Abutment Connections: A Review

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Abstract: *Success criteria for implants depends on numerous host factors, mechanical factors, biologic factors etc. Mobility, pain, radiolucency, and peri-implant bone loss (> 1.5 mm) were criteria to be evaluated for success at implant level, and suppuration and bleeding for success at the peri-implant soft-tissue level. Similarly, the occurrence of technical complications/prosthetic maintenance, adequate function, and esthetics during the five-year period were criteria for success at prosthetic level. The criteria at patient satisfaction level were discomfort and paresthesia, satisfaction with appearance, and ability to chew/taste.[1]This review article analyses the type and importance of fixture abutment interface position, platform switching and biomechanical factors on prognosis.*

Keywords: *fixture abutment interface(FAI), implant position, external hex, Internal hex, platform switching, microgap, surface modification, microbial colonization, one piece and two piece implants*

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I. Introduction

The biologic considerations of soft tissue as well as hard tissue implant interface plays an important role during diagnosis and treatment planning phase of implant placement.[2]

This includes various factors like biocompatibility of material selected, surface modification, precise,aseptic and atraumatic techniques, position and configuration of implant abutment connection also time and phase of loading.which in turn influences the hermetic seal

ONE PIECE AND TWO PIECE IMPLANTS-A COMPARISON

One piece implants have a strong unibody design that mimics natural tooth.The single stage surgical technique can be either flap or flapless approach further simplifying the restorative technique. This also minimize the requirement of multiple surgical techniques and prosthetic components, thereby reducing the inventory and cost. One piece implants can be used in case of narrow labiolingual width and limited interdental space, mandibular anterior maxillary laterals and first bicuspids. one piece implants can be successfully placed in bone and can be either left unloaded or can be loaded progressively or immediately, because of the uni body structure. Absence of microgap reduces the restorative time and good primary stability is achieved. inbuilt abutment in one piece implants are prepared with proprietary tungsten carbide burs (TC) following the principles of Fixed partial denture preparations. This is followed by impression making with suitable impression techniques of putty wash or custom tray with single mix technique. Hence,this can be used for immediate placement with ease of obtaining an emergence profile.

The use of Two piece implants in a narrow edentulous space is a mechanical challenge as it remains structurally weak (lack of space to accommodate the connecting screw or thin screw) which lead to repeated screw breakage. The surgical protocol of two piece implant system (open flap technique) required the implant to be submerged and heal unloaded for a period 3 to 6 months. The healed implants required a second stage surgery to expose the submerged implants and Trans gingival component (TSG) was attached at this stage and the soft tissue was allowed to heal. [3][4][5]Presence of micro gap between two analogues of implants can lead to development of micro-organisms followed by inflammation of soft tissue around the implants that leads to implant failure which can avoided with use of one piece implants.Two piece implants require multiple prosthetic components such as impression copings and laboratory analogues. Moreover, the impression coping required is different for closed tray and open tray impression technique. [6]

No clinically significant effect on success, survival rates and marginal bone levels with use of one-or two-stage surgical techniques However, the one-stage technique has less morbidity since it involves a single surgical exposure, but the two-stage surgery might offers greater potential for soft tissue management can be attained by the two-stage surgery. Whether guided surgical protocols are followed or not is yet factor to determine the choice of whether to use one piece or two piece mini implants .In case guided implant surgery (that eliminate angulation problems) are to be performed, given the simpler procedure one-piece mini-implants might be the treatment of choice.However, when guided surgery is not a viable option, two piece mini-implants are preferred.[7][8][9]

IMPACT OF SUPRA-CRESTAL, CRESTAL AND SUBCRESTAL POSITION OF FIXTURE ABUTMENT INTERFACE ON BONE LEVEL

Aim of placement of the fixture abutment interface in a more apical position is to create an ideal emergence profile for the prosthetic construction and thereby more esthetic restorations. (Buser & von Arx 2000).But supracrestal positioning of the machined collar(smooth or rough border) at both one- and two-piece implants may be favored over a subcrestal positioning since the net bone loss at implants exhibiting a subcrestal insertion of the machined neck was even more pronounced than crestal or supracrestal fixture- abutment interface.[10]11][12][13][14]

Todescan et al in 2002 reported that the first marginal bone to implant contact was located between 1.6 mm and 2.5 mm apical to the FAI with the shortest distance associated to that of subcrestal position.[15]

Hämmerle et al. 1996. Compared one-stage transmucosal implants placed with the border between the rough/smooth surface 1 mm subcrestally to implants placed according to the manufacturer' s recommendation with the rough/smooth border positioned precisely at the alveolar crest. The implants within the subcrestal group lost a mean of 2.26 mm of clinical bone height during the initial 12 months,while the control implants lost 1.02 mm during the same time period.[16]

Placement of the FAI in subcrestal position has been documented to posess positive effect on marginal bone levels for implants with reduced abutment diameter in reference to the fixture diameter, a Morse taper implant-abutment connection and a microstructure[17]

As microbial leakage apparently didn't contribute to the marginal bone resorption at either CAM or CAM+ implants (Schwarz et al. 2008;Steinebrunner et al. 2008), the pronounced bone remodeling at subcrestally inserted machined necks was mostly attributed to their reduced osteoconductive surface properties (Wennerberg & Albrektsson 2009)[18][19][20]

IMPACT OF DIFFERENT TYPES OF FIXTURE ABUTMENT CONNECTION ON PROGNOSIS

FAI can be categorized as a **slip-fit joint** where a space exist between the implant – abutment interface or a **frictional fit** where there is minimal space at the interface. Different geometrical designs available are octagonal, hexagonal, cone screw, cone hex, cylinder hex, sline cam, cam tube and pin / slot [21]

A) ***EFFECT ON CRESTAL BONE LEVEL***

Astrand et al. (2004) reported that bone volume was of greatest change during the period following implant placement and before superstructures were constructed for patients who received either internal or external hex abutments. However, the quantity of crestal bone lost was small between initial stage and follow up visits at 1, 3, and 5 years and didn't differ significantly between internal and external hex implants.

Weng et al. (2008) conducted a comparative study histologically between degree of bone loss seen in the internal taper and external hex connections of implant systems with either epicrestal or subcrestal placement in animals. Bone level around implant at 3 months visit after abutment connection showed minimal change for epicrestal placement of implants with an internal taper ficture abutment connection.

Finite element analyses and literature (Maeda et al., 2006; Pessoa et al., 2010; Nishioka et al., 2011; Chu et al., 2012; Streckbein et al., 2012) indicates that the configuration of implant– abutment connection may influence the stresses and strains induced in periimplant crestal bone.Chu et al. (2012) further demonstrated that either increasing the thickness of the inner wall of the implant body or decreasing the width of the implant–abutment connection reduces the stress in the peri-implant bone

The studies conducted by Engquist et al Astrand et al. Lin etal compared the effects of external hex, internal hex,internal octagon, and internal Morse taper implant–abutment connections on the peri-implant bone level before and after the occlusal loading.Lin etal Crestal bone change did not differ significantly among different types of implant– abutment connections, but it was slightly greater—60% for external hex and 52% for both internal octagon and internal Morse taper—during the healing phase (before occlusal loading) than during loading phases 1 and 2 (3 and 6 months after occlusal loading, respectively). Reasons were surgical trauma, occlusal overload, peri-implantitis, the microgap, the biological width, and the implant crest module used (Oh et al., 2002) well within the success criteria proposed by Albrektsson et al. (1986; i.e., amount of bone loss < 1.5 mm in the first year) [22]

B)EFFECT ON BIOLOGIC WIDTH AND SOFT TISSUE ESTHETICS

Although obtaining biological width depends on many other factors like the presence of parafunctional habits as in bruxism, gingival biotype, and position of the implant, but the configuration of implant abutment connection also plays a crucial role. The presence of microgap, bacterial infiltrated, and existence of abutment micromovement all of which predisposes it to bacterial contamination and hampers the biological width [23]

The biological width was significantly greater for 2-piece implants than for unibody implants in the study of Hermann et al. (2001), and this was attributed to the presence of an microgap at or below the crest of the bone[24]

When compared with external abutment connections, internal connections show higher efficacy in terms of mechanical strength, stress distribution, microgap, and bacterial penetration; thus implants supported with internal abutment connections preserve biological width better.When internal abutment connections were compared with each other, Morse tapered connections distributed stress better at the alveolar bone level and displayed better resistance to bacterial leakage[25]

Studies indicated that a stable vertical and horizontal dimension of healthy periodontal soft tissue, the biological width, is an important factor in the consideration of soft tissue esthetic result (Abramsson et al. 1996; Berglundh & Lindhe 1996; Cochran et al. 1997; Hermann et al. 2000, 2001).

Apart from Surgical methods like a connective tissue graft to enhance soft tissue thickness esthetic crown-lengthening, flapless surgery and immediate implant placement with or without immediate loading and restoration there are limitations to the esthetic appearance in cases with thin peri-implant mucosa leads to display of the underlying titanium implant with a grayish appearance of the gingival cuff.

In a study to investigate the optical effects of eight different implant neck colors (white, black, light pink,pink, light orange, orange, gold, violet) transmitted through the peri-implant marginal mucosa, and to provide an optical solution for eliminating the undesirable shine-through effect by selecting an optimized implant neck color based on an objective and quantifiable method. Spectrophotometric measurements were made using a multi-spectral camera system.

The goal of evaluating the color difference is to achieve the smallest DE value possible, indicating the most accurate shade match. Following insertion of light pink, pink, light orange and orange color strips, a less color difference in periimplant tissue was measured compared with the corresponding adjacent or contralateral natural gingiva. When a color strip was compared to the target color of the adjacent or contralateral control sites,it showed little darker as was the case with colors violet and gold. [26]Dark color strips negatively affected the peri-implant tissue esthetics in terms of color as soft tissue is partially translucent. When colors similar to that of natural gingival tissue was used for the implant neck, the test site was able to reproduce the target color more satisfactorily.Zirconium oxide and aluminum oxide ceramic abutments because of their ability to allow transmission of light had better esthetic display. Zirconia abutments have shown survival rates and fracture strengths similar to metal abutments and offered sufficient stability.Ceramic thickness of 1.5mm has been shown to influence the final shade from the color of abutment underneath the crown (Vichi et al. 2000; Nakamura et al.2002). Thus, there is substantial advantage in studying implants with specific neck colors to improve soft tissue appearance.

To achieve an acceptable esthetic result, the mesiodistal and buccolingual implant position and angulation in the residual alveolar ridge, the minimal interocclusal distance, and the maximal interproximal contact point to crestal bone distance each must approximate 6 mm.

C)EFFECT ON MICROBIAL COLONISATION

Peri-implantitis and the loss of osseointegration is influenced by bacterial plaque accumulation at the level of implant-abutment-connection (IAC) and once colonized may act as a bacterial reservoir.According to Lauritano et al,the total bacterial count average in screwed implant-abutment connection was 3.7×10^8 and those in cemented implant-abutment connection was 2.1×10^8, recording no statistically significant differences ($p = 0.32$). The pathogenic threshold of this latter group was overcame in the case of five bacteria (Porphyromonas gingivalis, Tannerella forsythia, Treponema denticola, Prevotella intermedia, Campylobacter rectus), while the bacterial colonization of peri-implant sulci was over for only one bacterium (Prevotella intermedia). While the “purple”, “yellow”, and “green” complexes are not associated to disease, the “orange” (F. nucleatum,P. intermedia, M. micros) and “red” complexes (P. gingivalis, T. forsythia, T. denticola) are disease-related. A. actinomycetemcomitans is also considered as being periodontopathogenic, although it is not included in any group.

Implant diameter ,implant design (conical or cylindrical),and its coil, implant length, material abutments are made of determines osseointegration and long term stability. Zirconia abutments are higher chances to have microleakage than titanium abutments and these should be used only in cases where there was a very high demand for aesthetics, surgical technique; and bone characteristics, such as density and thickness.[27]

Microbial colonization of microgap depends on the precision fit between the implant components, which is associated with the implant system design, the torque used to connect the components, and the repeated screw loosening and re-tightening.A micro gap between 40-60μm occurs at the IAC with different implant systems due to micromovements.

Internal hexagonal connection ensures proper abutment seating, anti-rotational engagement,resistance to lateral forces, and excellent aesthetic results and reported as being less favorable to the infiltration of fluids than the external connection and higher stability to Occlusal loading. The performance of bridge rehabilitation was observed to be worse than that in single crown rehabilitations Though external hexagon are one of the oldest and commonly used abutment connections, they are considered to be ineffiecient in preventing microbial leakage at the implant-abutment interface.[21]

Among various In vivo and in vitro studies conducted to assess various connections used, Morse taper connections achieved higher seal as it has frictional lock system and thus reduced the bacterial infiltration at the implant-abutment interface.Conical abutments demonstrated superiority with regard to seal performance, micro-gap formation, torque maintenance,and abutment stability. Conical systems appear to control inconvenience resulting from micro movements and pump effect better than internal and external connections. Maintenance of Torque value between implant and abutment prevent abutment screw loosening or movement and also the micro-gap formation which is another factor that controls long term implant stability. Conical connection exhibited least amount of red complex bacteria as compared to external hexagon, and internal hexagon with external collar.[21]

According to the literature, the screwed implant–abutment connection showed cent percent implants colonized by bacteria versus 20% in the cement implant–abutment connection. Nevertheless, the cement-retained implant–abutment may show a cement related peri-implantitis.Different authors have obtained a significant reduction of the bacterial leakage at the IACs level,using a specific gel or a particular rubber ring (O-ring)(nayak et al), adhesive material(Arshad et al). protocol of rinsing the abutment and the inner part of the implant with chlorhexidine(Romanos et al).Siadat et al., found that the radiotracer technique,a precise technique to evaluate microgap.[29]

Higher contamination was observed with implants in which 20N.cm torque was applied in a study conducted to evaluate the bacterial leakage at the implant-abutment interface and the sealing efficiency of implants when they were subjected to in different torque values

The 11-degree Morse taper displayed no sign of microbial leakage during the 14-day period of evaluation.Thus, found to have better resistance to microbial leakage than a butt joint connection design. The higher mechanical stability of Morse taper connection facilitate it to be indicated in situations like single implants, fixed partial denture, and overdentures, since it showed higher mechanical stability. The accuracy in fabrication and precise fit of the components seem to be an important factor in resistance to leakage.[30]

IMPACT OF SURFACE MODIFICATION ON LONG TERM STABILITY

The stability of the abutment screw is mainly related to the preload force, surface friction coefficient and implant-abutment connection methods. Different connection methods affect the transmission of stress among the components of the system tapered connection increases the contact area of the two components, which can help the abutment screw resist lateral forces and improve the bending resistance better stability and fatigue performance

Yong-Hoon Jeong et al. prepared TiN (titanium nitride) and WC (tungsten carbide) films on the surface of the abutment screws using the EB-PVD (electron beam physical vapor deposition) method. The results showed that the coating with high strength and hardness could improve the fatigue characteristics of abutment screws. Elias et al measured the opening torque of abutment screws coated with four different materials (TiN, TiCN (titanium carbonitride), Teflon and Parylene). The results indicated that uncoated screws had a higher opening torque for a given applied tightening torque. Xi Chen et al. prepared PEEK (Polyetheretherketone) and PTFE (Polytetrafluoroethylene) coatings on the surface of the abutment screw by thermal spraying. They found that both coatings improved the performance of immediate fastening and long-term anti-loosening. There are methods to prepare coatings on the surface of abutment screws to enhance the stability and fatigue performance of dental implants. However, with these methods, the coating falls off due to external forces, which introduces unnecessary clinical hidden danger

Plasma nitriding is a recent development in surface modification technique, which can be used to enhance the surface properties (surface hardness, corrosion resistance, and wear resistance) of materials without an obvious boundary between modification layers and substrates Therefore, there is no risk of the tissue being inflamed due to the wear of coating..The purpose of this study is to investigate the long-term stability of plasma nitriding surface titanium alloy screws in connection implant with abutment by determining the preload force, fracture load, fatigue life, loosening torque and surface wear under static and dynamic loads. The nitriding treatment can improve the mechanical properties of the abutment screws by improving the surface hardness, corrosion resistance, and wear resistance the increase in deformation resistance also increases the fracture load of the dental implant. Furthermore, PNT has higher surface hardness and surface compressive stress, which enhance the fatigue life.

PNT prolonged the fatigue life, which was greater than the human average bite force and chewing force mainly since the nitriding treatment improved the deformation resistance of the system[31]

BIOMECHANICAL EVALUATION OF FAI AND EMERGENCE OF PLATFORM SWITCHING

The principle of Morse taper is that, of the cone in the cone where the trunnion and the bore are uniformly tapered. The bone is tapped into the trunnion as they contact and thus, the stresses inside the materials keep both components fixed together.[23]

Internal connections firstly showed increased fragility compared to the external connections, especially for the small diameters. This fragility is due to the concavity in the body of the implant intended to provide space for the implant abutment However, in vitro studies suggest that internal connections displayed greater resistance than external connections under heavy torque stresses.[32]Chun et al., 2006, demonstrated that internal hexagon connections distributed stress better within the implant and further redistributed within bone due to larger implant abutment contact area. In external hexagon connection, highest strain concentration was found between the implant platform and the abutment which indirectly led to compromised biological width.Resende *et al*. demonstrated the smaller amount of bone loss for Morse taper implants, both on the buccal and lingual sides, whereas external hex implants showed a larger bone loss Quaresma et al. in 2008 stated that the stress is better distributed at the alveolar bone but more pronounced at the abutment itself in Morse taper implant. Whereas internal hex abutments bring out greater stresses on the alveolar bone and the prosthesis but lower stresses on the abutment system .Failure of the abutments was system dependent and occurred predominantly in the region of the weakest point, the screws,respectively, the threaded parts, or between the threaded or unthreaded parts of the abutment Khraisat et al. reported a significant difference between the Morse taper and external hexagonal connection systems; in that no fractures were noted for the Morse taper group, while the mean fractures' rate for the external hexagonal groups was between 1733 and 1778 cycles.Higher maximal load resistance values(increased resistance to bending forces) were seen for the internal conical implant abutment as compared to the internal hexagonal connections with a two‑ piece abutment for the bacterial growth.[33] Numerous studies demonstrated the presence of bacterial growth within these spaces which directly influence the continuity of the biological width and may lead to marginal bone loss and peri‑ implantitis.

A comparative study conducted by Jaworski *et al.*, 2012,demonstrated significant lower bacterial penetration within Morse taper (30% of cases)(cold welded interface) against external connections (60%) When compared between Morse tapers and internal connections, Tripodi *et al*. in 2012 demonstrated that 2 out of the 10 Morse taper implants were colonised against 5 of the internal hexagon connection implants[34][35]

PLATFORM SWITCHING

Platform switching concept introduced by Lazzara and Porter was based on the hypothesis that a narrower abutment can increase the distance between the implant‑ abutment microgap contamination and the crestal bone and may allow the establishment of an adequately sized biological width, thus reducing bone resorption. Forces were concentrated more toward the center of the implant which was further distributed into the bone. Thus, the tissues at the fixture abutment interface are under less stress.Since internal connections are often associated to platform switching remains beneficial against external connections.Platform switched morse taper connections showed reduced inflammation and bone loss. Hence, Morse taper connection preserves the biological width compared to other internal connections.In terms of mechanical and structural integrity, conical abutment connection systems are more resistant to micromovements and microgaps, better torque resistance and higher resistance to fatigue loading and maximum bending[36][37][38]

II. Conclusion

Implant-abutment junction is the weakest part of the implant restoration complex, both from a mechanical point of view and, mostly, from a biological standpoint.

A recent advance of smooth concave trans mucosal one piece implants ,neck brings the IAJ (and its micro gap) in the soft tissues, away from marginal bone. It provides an increased space for soft tissues maturation and the establishment of a biological width. The incremented contact area also provides major volume (wider surface area with same vertical dimension) and thicker soft tissue seal around the implant thus bacterial accumulation and progression to peri implantitis. The formation of a mucosal attachment to the implant seems to be promote bony overgrowth instead of loss. The distance of 1.5 mm between the IAJ and the implant shoulder can be considered as a "safe distance" that prevents potentially harmful periodontal flora, which usually extend apically from the epithelial junction to a maximum of 1.1 mm from reaching the first bone to implant contact.[39]

Re emergence of one piece implants is being further researched due to lacunae in use of two piece implants due to presence of micro gap, bacterial colonization, micro movements

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