Three-Dimensional Finite Element Analysis of Esthetic Custom made Hybrid Abutment Crowns with Different Angulations and Materials

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

{نَرْفَعُ دَرَجَاتٍ مَنْ نَشَاءُ وَفَوْقَ كُلِّ ذِي عِلْمٍ عَلِيمٌ}

صدق الله العظيم

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Dedication

I would like to dedicate this work to

My Parents,

My family,

&

My beloved friends

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Introduction

Restoring missing teeth is a main concern in dentistry, as by restoring these missing teeth function and esthetics are both restored. They have been restored either by fixed bridges or by removable partial dentures. Since the introduction of osseointegration by Branmark et al[1], dental implants have been used in replacing missing teeth, especially in replacing single teeth. Adelle et al[2] reported that 90% of implants placed in anterior mandible functioned 5 to 12 years later, and thus increased survival rates of implants allowed for the clinician use implants as their first choice in treatment planning. While in anterior maxilla the unpredicted bone loss as a result of teeth loss affected the survival rate of implants.[2] Thus, clinicians started to use angled abutments to increase the survival rate and improve esthetics, especially if implant was placed in an angulation.

Abutments were first made of titanium but in the process of developing new materials to improve esthetics dental ceramics were developed. Ceramic abutments are customized abutments that improved esthetics a lot and made restoring of missing teeth much easier, especially with the development of CAD/CAM technology. Screw retained or cement retained customized ceramic abutments could be fabricated in either ways.

Hybrid abutment crown is considered a custom abutment. It is a one unit abutment, thus its main advantage is that it combines the reliability of the titanium base with the high esthetics of ceramic materials. Also known as "the combination implant crown", it was suggested by McGlumphy et al[3], Rajan and Gunaseelan[4], and Uludag and Celik[5]. The design of this crown depends on cementing the crown to the implant's abutment extraorally, and this cemented assembly could be then screwed onto the implant through access screw channel in the restoration.[6]

To achieve optimized biomechanical conditions for implant supported prosthesis, stress/strains in bone-implant interface should be studied. Different testing methods have been used such as; photoelasticity, strain gauges and finite element analysis.[7]

In this study, custom hybrid angled abutments are studied using FEA. These hybrid abutments are designed in three different angulations 0º, 15º and 25º using four different ceramic materials Lithium disilicate, Yttria stabilized tetragonal zirconia, Polymer infiltrated glass ceramic and Zirconia-reinforced lithium silicate.

Review of Literature

In the past decades, treatment of edentulous areas mainly depended on Conventional Fixed bridge work, resin-bonded restorations, or removable partial denture.[8] But then a new era started in replacing missing teeth using dental implants when Branemark et al[1]. introduced the concept of osseointegration. Studies have showed excellent implant survival rates when applied for single tooth replacements.[9] Over the years, restoring the anterior maxillary zone using implants have become more challenging due to the increased demand for the accomplishment of optimal esthetics.

Anterior Zone

In the anterior zone, the success of implant therapy is not only determined by the high survival rates, but also with the esthetic appearance which depends on several factors such as perimplant soft tissue level, prosthesis level, and patient's subjective assesments.[10] Patients nowadays not only want to restore function but also want more natural appearance as they became more esthetically oriented and upto-date, thus increasing the high esthetic demand.

Esthetic Implant Restoration was defined by Higginbottom and colleagues[11] as the restoration that resembles the natural tooth in all aspects. Over the years, the dental literature has described several systems for evaluating esthetic outcomes of implant restorations in the esthetic zone.

A Pink Esthetic score (PES), was developed by Furhauser and colleagues[12], to evaluate the esthetic outcome of the soft tissues surrounding dental implant restoration. The criteria of this system were based on seven variables: Mesial papilla, Distal papilla, soft tissue level, soft tissue contour,

alveolar process deficiency, soft tissue color and texture.[12] Another objective comprehensive esthetic index was developed by Belser and colleagues[13], that links the PES with a white esthetic score (PES/WES). This system decreases the number of variables from seven to five variables which are: mesial papilla, distal papilla, curvature of the facial mucosa, level of the facial mucosa and root convexity, soft tissue color and texture around the implant. The PES/WES Index is being widely used to evaluate the esthetic outcomes of both implant placement and restorative techniques.[13] Establishing a soft tissue contour with intact papillae is the most difficult factor in achieving an optimal esthetic result. The height and thickness of the facial bone are important for the long term esthetic success rate, and that's why the quality and quantity of the facial bone should be considered before implant placement. In case of facial bone defects various surgical techniques could be done as a solution to overcome these defects such as guided bone regeneration and a combination of bone grafting and barrier membrane.[14]

Immediate implant placement in fresh extraction sites is considered a preventive technique to avoid the occurrence of bony defects after extractions.[15] Placement of implants in different angulations is done in some cases with bony defects. After implant placement, many factors could affect the restorative phase such as the healing abutment, provisional restorations, abutment connection, abutment diameter and the shape and color of the final restoration.[10]

It has been suggested that immediate placement of provisional restorations could perfectly affect the esthetics in the final restoration. As it is believed to guide the healing of gingival tissues with perfect emergence profile.[16] The position of the interdental papillae is the key for good emergence profile and the interdental papillae itself depends on various

factors such as proper contouring of subgingival abutment component, position of contact point and height of crestal bone.[17]

Abutments

Implant abutments play an important role in achieving good results during long term implant prosthetic treatment. The abutment connection as well is believed to have an obvious effect in increased esthetics, as the abutment should be narrower than the implant. Selection of implant abutment depends on several factors as: long term stability, accurate fit of the components to prevent screw loosening during function, biocompatibility and esthetics.[17] The types of implant-abutment connection can be divided into two major groups : internal connection and external connection. Sailer et al[18], reported that the internal implant abutment-connection type including zirconia abutment with titanium insert showed high strength than the external type.

The abutment's attachment to the implant can be achieved by screw retention, cementation or combination of both. Historically, the prosthetic components of implants were prefabricated one piece abutment crown restorations made of titanium veneered with acrylic resin.[19] Through years and in order to improve esthetics a two piece restoration was fabricated with a prefabricated titanium abutment supporting a cemented metal-ceramic crown.[20] Then, University of California Los-Angeles "UCLA" introduced the UCLA abutment in 1988[21]. This type of abutment is a customized cast metal component that is directly screwed into the implant.[21] The castable component is either does not engage the anti-rotational mechanism in multiple units or engage the anti-rotational in a single implant restoration.[22]

Screw retained restorations could be used anteriorly or posteriorly, but if used anteriorly it requires an implant angulation to facilitate the access to the screw through the screw channel, thus the implant platform is placed slightly lingual to the ideal implant position. That's why the retention system of the restoration should be determined before surgery. The screw retained restorations have a great advantage in overcoming the unfavorable implant angulation.[23] Although the screw retained restorations are easily handled clinically, but they have in versatility in design. As it is one piece restoration, porcelain fused to metal restoration; first the metal framework is waxed and then cast in a gold alloy, second the porcelain is fired to this abutment. Lately, with the new innovations in dental ceramics, ceramic abutments could be used as a base to which porcelain is added to form an all ceramic screw retained restoration.

On the other hand, the cement retained restoration is two piece prosthesis, consisted of an abutment and a crown.[24] It could be made of either titanium abutments and porcelain fused to metal crowns or of all ceramic abutments and crowns. This design offers a great clinical versatility, [24] although, clinical management of the restoration at the delivery and in-crown dislodgement. Normally, the desired countersinking of the implant platform is about "2-4 mm" at the midbuccal area, but because of the scallop of the gingival tissues, this countersinking could be about" 5-7 mm" from the tip of the papilla to the implant platform at the interproximal area of an anterior tooth. Thus, the abutment's margin should closely follow this gingival scalloping to maintain a clean working field during cementation.[25]

A hybrid design of both types of restorations was developed to avoid the disadvantages of each.[22] Combining both designs was introduced by using at least 1 screw retainer into a chain of cement retainers within the

same restoration.[26] Another technique was developed using abutment inserts, where a standard abutment perforated on the lingual side is screwed to the implant and an insert is cast to fit tightly into the abutment in a lock and key fashion and lodges into the screw of the implant to secure it. Then the restoration is made with the same lingual hole found in the abutment to match with it and with that of the insert through a spring locked pin.[27] The concept of abutment customization has been developing over the years, to overcome the esthetic failures of the titanium stock abutments. As a shine through effect of the underlying titanium implant abutment showing an undesirable greyish color, and also any apical recession around the implant could reveal the abutment or the implant surface that could affect esthetics significantly.[28-29]The alumina ceramic customized abutment was a major breakthrough especially with the development of Computer Aided Design Computer Aided Manufactured (CAD/CAM) technology.[30] Glauser and collegues[31] in 2004, described the densely sintered ytterium-stabilized zirconia is to be a substitute for the ceramic abutment. A manually guided copy milling technique was used to produce the abutment as a copy of customized resin design.[31-32] These zirconia customized abutments were then designed and produced using CAD/CAM technology.

Other type of abutments made with titanium insert called Hybrid Abutment Crown.[32] Customized implant abutments have a great advantage as it gives the ability to control the transition contour and to locate the finish line to enable residual cement removal.[22] Hybrid abutment crowns could be used in patients with gingival recession or thin gingival tissues in esthetic areas. Studies have shown that hybrid abutment crowns have good marginal seal with the border of the implant which serves for the longevity of the implant-crown complex.[33] Hybrid implant abutment crowns have the