RESEARCH ARTICLE

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Effect on the Fracture Resistance of Monolithic Zirconia Custom Abutment in Different Angulation: An *In Vitro* Study

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ABSTRACT

The study was designed to find out the effect of different angulations of monolithic Zirconia custom-made abutments on fracture resistance. In this experimental type in vitro study, a total of thirty implant analogs with a diameter of 4.3 mm and a length of 11.5 mm were obtained for the maxillary central incisor. A total of thirty abutments specimens in three groups- 0-degree, 15-degree, and 25-degree, ten in each group were fabricated with monolithic zirconium by CAD/CAM system. Each abutment was subjected to load until fracture in a Universal testing machine and data was collected to a data collection sheet. One-way ANOVA was done to compare the fracture load among the three groups and pairwise comparison was done by Tukey post hoc test. The statistical significance p-value was considered as less than 0.05. The range of fracture load of 0-degree, 15-degree, and 25-degree angulated abutments were 590.55-1305.43N, 755.89-1720.55N, and 496.68-820.88N respectively. The highest fracture resistance was shown in 15-degree angulated custom-made zirconium abutments with a mean ± SD of 1223.442 ± 317.771N and the lowest fracture resistance was shown in case 25-degree with a mean ± SD deviation of 653.139 ± 102.045N. The mean ± SD of the 0-degree abutment was 948.944±245.588N. 95% Confidence interval of the mean were 773.260-1124.627N, 996.122-1450.761N, and 580.140-726.137N were assessed in cases of 0-degree, 15-degree, and 25-degree respectively. The fracture load or fracture resistance among the three groups of custom-made monolithic zirconium abutments were significantly different. 15-degree angulated abutment had higher fracture resistance properties. straight abutment had more fracture resistance properties than that of 25-degree abutments, but less than 25-degree abutments.

Keywords: Angulated implant abutment, CAD/CAM system, fracture resistance, monolithic Zirconia custom-made abutments.

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I. INTRODUCTION

Dental implants have been used to support prostheses to replace all teeth of the completely edentulous arch as well as single or multiple teeth of partially edentulous arches. To replace a missing tooth, the dental implant usually consists of the implant body and the abutment to which the artificial crown is attached [1]. The abutment-crown complex was first introduced in 1986. Later this abutment-crown complex was changed to two parts consisting of prefabricated titanium abutment on which a metal-ceramic crown can be cemented [2]. According to the fabrication technique, abutments are of two types- prefabricated abutments and custom abutments. CAD/CAM technology is used to make custom abutments with titanium and ceramic [3]. In Germany, CAD / CAM technology is introduced in 1988 in dentistry [4], [5]. Custom abutments that are made by CAD/CAM technique are made from a block of titanium or ceramic. The cast is scanned to generate 3D images of the region and the information is sent to the milling machine and the abutment is produced [6]. Custom-made abutments can be used in any clinical situation to replace a single tooth because customized abutments can be adjusted more effectively to the local clinical situation than prefabricated abutments [7]. Zirconia abutments had several advantages in comparison with titanium abutments [8], [9]. The selection of abutment depends on different factors. Customizing an abutment gives the clinician the freedom to its position and angulation considering function and esthetics [10], [11]. Prosthetic customization of the implant abutment can accommodate for the osseous topography concerning the prosthetic crown, with a highly clinically observed 2-year survival of titanium abutments often angulated in the range of 5°-30° [12], [13]. Zirconia has the highest flexural strength and fracture toughness among all ceramics [14]. Despite the enhanced material properties of zirconia ceramic failures of zirconia abutments have been observed clinically [15], [16]. Additionally, lower fracture resistance has been reported in vitro when combining lithium disilicate or zirconia crowns with zirconia abutments, compared to cementing them on titanium abutments [17], [18]. Various clinical and mechanical parameters have been investigated to minimize the fracture incidence under function, with recommendations on the thickness and design of the zirconia abutments, as well as the fabrication process and treatment of the material [19]. Several studies had been conducted to assess the factors responsible for fractures [20]-[26]. The majority of them focused on the diameter and thickness of the abutment. A few studies evaluated the role of abutment angulation on fracture [22], [23]. As no conclusive results exist in the literature on the angulation threshold of internal connection one-piece zirconia abutments, the purpose of the present in vitro study was to further investigate the relationship between the implant-abutment angulation and the fracture resistance of zirconia ceramic abutments.

II. Materials and Methods

This experimental type of *in vitro* study was conducted in the department of Prosthodontics, faculty of dentistry, Bangabandhu Sheikh Mujib Medical University, Shahbag, Dhaka. The study samples were customized monolithic zirconia abutments formaxillary central Incisors made by CAD/ CAM technology with 0-degree, 15-degree, and 25-degree angulations. A total 30 samples were used, 10 in each group. Thirty internal connection implant analogs with a diameter of 4.3 mm and length of 11.5 mm were obtained from Nobel Biocare. They were divided into three groups- ten in each group. Group A- simulated an implant abutment with 0-degree angulation, Group-B -simulated an implant abutment with 15-degree angulation, and Group-C- simulated an implant abutment with 25-degree angulation. A gypsum model that incorporated the implant replica to replace the maxillary central incisor region was scanned for the construction of monolithic zirconium abutments. Zirconia abutment with angulation of 0-degree was digitally designed for using Densply Sinora MC X5 in Lab software. The digital file was copied for 15-degree and 25-degree abutment designs. Modification of 0-degree was done to 15-degree and 25-degree. Total of thirty monolithic zirconium abutments, ten in each group (0-degree, 15-degree, and 25-degree) was fabricated. A wax platform with inlay casting wax was added on the incisal edge on the 15-degree and 25-degree abutments.

All abutments were further embedded in self-cured acrylic resin using a dental surveyor. The arm of the dental surveyor was replaced by the machine indenter which created a 1350 angle with the abutment. This angle further represented the angle between the custom abutments and the universal testing machine. The abutments were placed in the Universal testing machine in such a way that the indenter formed a 135° angle to the long axis of the abutment. The load was applied to the abutments until failure occurred either an audible crack and/or a visual crack. The maximum load at which fracture occurs was collected on the data collection sheet.

Statistical analysis was performed using software (SPSS 20.0 version; In, Chicago, Ill). The mean and the standard deviations and the 95% confidence interval of the mean of the fracture load of each group were calculated. A one-way ANOVA was done to compare the fracture load among the three groups and a pair wise comparison was done by Tukey post hoc test. The statistical significance p-value was considered as less than 0.05.

Table I shows descriptive statistics of the fracture load of zirconium abutments in different angulations. The range of fracture load of 0-degree, 15-degree, and 25-degree angulated abutments were 590.55-1305.43N, 755.89-1720.55N, and 496.68-820.88N respectively. The highest fracture resistance was shown in 15-degree angulated custom-made zirconium abutments with a mean ± SD of 1223.442±317.771N and the lowest fracture resistance was shown in case 25-degree with a mean ± SD of 653.139±102.045N. The mean ± SD of the 0-degree abutment was 948.944±245.588N. 95% Confidence interval of the mean were 773.260-1124.627N, 996.122-1450.761N, and 580.140-726.137N were assessed in cases of 0-degree, 15-degree, and 25-degree respectively.

Table II shows a one-way ANOVA test to compare fracture load in three different groups of custom-made zirconium crown- 0-degree, 15-degree, and 25-degree angulations. The result showed the fracture load or fracture resistance among three groups of zirconium abutments were significantly different.

Table III shows pairwise comparisons between groups of zirconium abutments. All comparisons resulted in significant differences in fracture load among the groups. Between 0-degree and 15-degree angulated abutments, 15-degree abutments were significantly more fracture resistance, between 0-degree and 25-degree abutments, 0-degree abutments were more fracture resistance and 15-degree abutments showed more fracture resistance than 15-degree abutments.

TABLE I: Descriptive Statistics of the Amount of the Fracture Load (N)[a] of Custom-made Zirconium Abutment in Different Angulations

Angulations	Minimum	Maximum	Mean	SD[b]	95% CI[c] of mean	
					Lower	Upper
0-degree	590.55	1305.43	948.944	245.588	773.260	1124.627
15-degree	755.89	1720.55	1223.442	317.771	996.122	1450.761
25-degree	496.68	820.88	653.139	102.045	580.140	726.137

a, Newton, b, Standard deviation, c, Confidence interval

TABLE II: Comparison of Fracture Load in Custom-made Zirconium Abutments with 0-degree, 15-degree, and 25-degree Angulations by One-way ANOVA

	Sum of Squares	df[a]	Mean Square	F-value	P-value
Between groups	1626984.206	2	813492.103	14.213	0.000 (<0.05)[b]
Within groups	1545351.031	27	57235.223		

a, degree of freedom, b, a statistically significant p-value

TABLE III: PAIRWISE COMPARISONS OF FRACTURE LOAD OF LOAD IN CUSTOM-MADE ZIRCONIUM ANGULATED ABUTMENTS BY TUKEY POST HOC TEST

Comparison groups	Mean±SD	Mean Difference	P-value
0-degree and 15-degree	948.944±245.588 1223.442±317.771	-274.49800*	0.041 (<.05)
0 degree and 25-degree	948.944±245.588 653.139±102.045	295.80500*	0.027 (<.05)
15-degree and 25-degree	1223.442±317.771 653.139±102.045	570.30300*	0.000 (<.05)

III. DISCUSSION

Modern dentistry is expanding day by day. The dental implant is the exclusive part of modern clinical dentistry. World widely as well in our country the popularity of dental implants is increasing day by day. The success of dental implants has been documented by a few researchers more than 90% [27]. Implant abutment fracture is one of the common causes of failure of dental implants in the patient's mouth [28]. There are many factors responsible for fracture of implant abutments- heavy occlusal load, faulty design of implant superstructure, implant-abutment angulation, implant-abutment diameter, metal fatigue, etc [29], [30]. This study aimed to evaluate the effect of implant-abutment angulation on fracture resistance.

Three types of angulated-0-degree, 15-degree, and 25-degree were subjected to load until fracture occurred. Each group consisted of 10 custom-made monolithic zirconium specimens fabricated by CAD/CAM technology. The minimum force required to fracture was 496.68N and the maximum force was 1720.55N. The range of fracture load of the 0-degree angulated abutments was 590.55-1305.43N, of the 15-degree angulated abutments was 755.89-1720.55N, and of 25-degree angulated abutments was 496.68-820.88N. The highest mean ± standard deviation, 1223.442±317.771N, of fracture load was found in 15-degree angulated custom-made monolithic zirconium abutments with 95% Confidence interval of 996.122-1450.761N. The lowest fracture resistance was shown in 25-degree angulated abutments with a mean ± standard deviation of 653.139 ± 102.045N and a 95% Confidence interval of the mean, 580.140-726.137N. The mean ± standard deviation of the 0-degree abutment was 948.944 ± 245.588N and the 95% Confidence interval of the mean was 773.260-1124.627N (Table I). The mean differences among the three groups of angulated monolithic zirconium abutments resulted in a significant difference (Table II). In the present study, 15-degree angulated monolithic custom-made zirconium implant abutments showed the most fracture resistance properties compared to that of 0-degree and 25-degree angulated abutments, that is, this group of implant abutments required the most load to fracture. 25-degree angulation had the highest negative effect on fracture resistance.

The results of this present study were in agreement with research papers done by [31]-[33]. The present study's findings supported these studies' results to a certain level. Reference [31] reported that 15-degree angulated abutments had higher fracture resistance properties than straight and 25-degree angulated abutments as we found in this study. Reference [32] concluded that as the angulation increased, fracture resistance compromised. We also found that 25-degree angulated abutments had the lowest fracture resistance. Reference [33] reported that 15-degree angulated abutments had the highest fracture resistance and 25-degree had the lowest. But there was a dilemma regarding straight or 0-degree abutment. Some researchers found that 0-degree abutments had better fracture resistance than 25-degree abutments, on the other hand, few did not support this. The increased implant abutment angulation resulted in increasing the lateral stresses that are responsible for the negative effect of angulation on fracture resistance.

Monolithic zirconium as a dental implant material and restorative material was gaining popularity over the past few years, this is because of having good mechanical properties and esthetic properties to fulfill the demand of patients. The fracture load of zirconium was reported between 900 to 200 MPa, the highest fracture strength among all dental materials available in dentistry [34], [35]. The current study was designed to assess fracture resistance under vertical load in vitro. In the mouth, an abutment was subjected to different cyclic loads-vertical, horizontal, and rotational in a salivary environment. The actual clinical performance of an abutment cannot be assessed by experiment in the laboratory. The application of vertical load in the laboratory was the main limitation of this experiment.

One of the important factors of fracture resistance of zirconium was the thickness of the material. A study done by Reich et al. reported that if the thickness of zirconium is reduced from 0.5 mm to 0.3 mm, fracture resistance is also reduced to 35% [36]. On the other hand, it was also concluded that poorly designed and excessively thick layers of zirconium undergo more fracture and have the least fracture resistance property [37]. So only the angle of the zirconium implant abutment cannot determine the clinical performance of a dental implant.

IV. CONCLUSION

It can be concluded that 15-degree angulated abutments had higher fracture resistance properties. With the increased angulation from 15-degree, fracture resistance had been decreased. Straight abutments had more fracture resistance properties than 25-degree abutments, but less than 25-degree abutments.

CONFLICT OF INTEREST

Authors declare that they do not have any conflict of interest.

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