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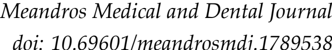

Meandros Medical and Dental Journal
doi: 10.69601/meandrosmdj.1789538

Research Article

THE EFFECT OF IMPLANT ANGLE AND TI-BASE ABUTMENT HEIGHT ON MONOLITHIC ZIRCONIA CROWN RETENTION

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Received: *07 October 2025*
Revised: *04 February 2026*
Accepted: *10 February 2026*
Published: *24 June 2026*

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ABSTRACT

Objective: This study aimed to evaluate how different Ti-base abutment heights (3.5 mm and 5.5 mm) affect the retention of monolithic zirconia crowns placed on straight (0°) and angled (15°) implants.

Material and methods: Sixty monolithic zirconia crowns were fabricated and assigned to four groups according to implant angle and Ti-base height. After CAD/CAM fabrication and standardized cementation, all specimens underwent a pull-out test using a universal testing machine, and maximum force at cement failure (N) was recorded. Due to variance heterogeneity, Welch ANOVA and Tamhane T2 post-hoc tests were used for analysis.

Results: Welch one-way ANOVA revealed a statistically significant difference in maximum load among the four experimental models (Welch $F(3, 29.49) = 86.08$, $p < 0.0001$). Tamhane T2 post-hoc analysis showed significant differences between all group pairs ($p < 0.05$), except between Model 1 (0°, 3.5 mm) and Model 3 (15°, 3.5 mm) ($p = 0.862$). The highest mean maximum load was observed in Model 4 (15°, 5.5 mm) (969.66 N), followed by Model 2 (0°, 5.5 mm) (736.24 N), while the lowest value was recorded in Model 3 (15°, 3.5 mm) (267.10 N). Overall, specimens restored with 5.5-mm Ti-bases demonstrated approximately a three-fold higher maximum load compared with those restored with 3.5-mm Ti-bases.

Conclusions: Implant angulation did not affect maximum load capacity in groups with 3.5-mm Ti-base abutments but produced a significant difference between groups with 5.5-mm Ti-base abutments. Overall, increasing Ti-base height significantly enhanced the maximum load capacity for crown retention. Clinically, using the longest appropriate Ti-base height may reduce the risk of crown detachment, especially in angled implant cases.

Keywords: Dental Implant Abutment, Zirconia, Dental Prosthesis, Implant-Supported, Titanium Base Abutment

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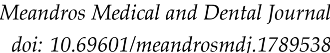
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INTRODUCTION

Implant treatment is a frequently preferred treatment option in dentistry for its predictable result, high success and survival rate, and restoration of lost function and aesthetics (1).

Prosthetic components of dental implants have been developed to improve biocompatibility, marginal compatibility, and aesthetics to overcome the deficiencies identified during the use of implants and implant restorations. As a result, abutments, which are one of the basic components of the restoration, which provide an improved connection with the implant, and are produced with different techniques and materials, have been used (2).

Titanium is the most widely used metal alloy in the production of abutments due to its biocompatibility, corrosion resistance, low molecular weight, low density, and high tensile strength (1). Titanium abutments are considered the gold standard for implant-supported restorations (3).

Titanium-base (Ti-base) abutments are systems that are cemented to a prefabricated titanium part of ceramic crown restorations produced with CAD/CAM, such as zirconia, and are preferred by many clinicians today. While the use of ceramic materials for crown fabrication provides an aesthetic advantage, the connection of the abutment and the implant in titanium provides an advantage in terms of mechanical reliability (4, 5).

In fixed prostheses on implants, the angled placement and positioning of the implants are important in terms of the prosthesis's biomechanics. Following tooth loss, the physiological process of bone resorption combines with sinus pneumatization (sagging). This situation often prevents traditional implant placement in the posterior region (6). There are several alternatives, such as bone grafting and sinus lift techniques, to increase the remaining bone height to allow patients to receive stable rehabilitation. These treatment procedures can result in various complications and additional costs (7). To avoid the risk of complications and extended treatment time, short implants (8) and angulated implants have been proposed as viable alternatives. The advantages of angled implants include their stability at minimum bone volume, eliminating the need for bone grafting, allowing placement that avoids anatomical structures, being an effective and safe alternative to maxillary sinus floor augmentation procedures and pneumatized maxillary sinus, better load transfer of distally angled implants compared to vertical implants (9), excellent long-term prognosis and good clinical results (10). Eduardo Piza Pellizzer et al. found in a study that the stress values on the implant and adjacent bone increased as the angle of the implant increased (11). Similarly, a different finite element study has found high deformation values in the cervical region of the bone around the angled abutment model (12).

To predict the behavior of materials under clinical conditions, in vitro testing with a clinically relevant design and thermomechanical artificial ageing is required. Retention tests by using pull-out forces have been suggested (4). Bond strength tests are widely used to evaluate adhesive performance; however, they cannot completely replicate intraoral conditions. Among these, the pull-out bond strength test is commonly used to assess the adhesion between an abutment and its superstructure, particularly in two-piece abutment systems (3). The pull-out test was chosen because it is a well-established and widely used method for evaluating the maximum load required to separate crowns from abutments (13).

A review of the literature showed that most studies have focused on the fracture resistance of crowns on Ti-base abutments, whereas only a few have examined how different Ti-base heights on straight implants affect the retention of zirconia restorations. Moreover, although some studies have evaluated the influence of CAD/CAM abutment height and cement type on the retention of zirconia crowns (14,15), there is a lack of data on how implant angulation affects retention. Therefore, the aim of the current study is to investigate the effect on retention using different Ti-base heights on the implant placed straight and at a 15-degree angle. The first null hypothesis of the study is that implants placed at different angles will have no effect on retention, while the second null hypothesis is that implant abutments with different heights have no effect on retention.

MATERIALS AND METHODS

Implant analogs (Osstem Implant Co. Ltd., Seoul, Korea) were placed in standard blocks (15x15mm) prepared with autopolymerizing acrylic resin (Akrodent, Koca Kimya ve Dental LTD. ŞTİ., Ankara, Turkey) at 2 different angles, 0 degrees and 15 degrees to the sagittal plane. To standardize the orientation of the implant long axes relative to the direction of occlusal loading, a dental surveyor was used. Using this method, the implants were positioned and stabilized within the acrylic blocks at 0°

and 15° angles during polymerization. The specimens were divided into 4 groups with different angles (0 and 15) (16) and different Ti-base abutment lengths (3.5 and 5.5 mm) and are given in Table 1. (Figure 1) The four different groups in the study can be listed as follows: Model 1: 3.5 mm Ti-base length, 0° angle; Model 2: 5.5 mm Ti-base length, 0° angle; Model 3: 3.5 mm Ti-base length, 15° angle; Model 4: 5.5 mm Ti-base length, 15° angle (n=15). To determine whether there were differences between the four distinct groups identified in the study, a one-way analysis of variance was used under the assumption of normality. Accordingly, it was estimated that a minimum sample size of 7 per group was required for 80% power at a significance level of 0.05 and an effect size of 0.704. The study's power was calculated using the G*Power 3.1.9.2 software package. Although there were seven samples for each group according to the power analysis results, we determined the number of samples per group to be 15, considering that this would be beneficial in obtaining more reliable results, as some studies in the literature had a higher number of samples per group (14, 15).

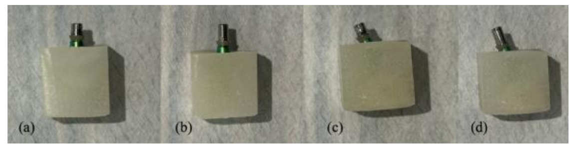

Figure 1. Implant analogs attached to Ti-base abutments embedded in acrylic. (a) Model 1: 3.5 mm Ti-base length, 0° angle; (b) Model 2: 5.5 mm Ti-base length, 0° angle; (c) Model 3: 3.5 mm Ti-base length, 15° angle; (d) Model 4: 5.5 mm Ti-base length, 15° angle

The Ti-base abutments on the prepared study models were screwed and torqued with 30 Ncm and scanned with a model scanner (Redon, Edge; Redon Technology). Maxillary first molar restorations were designed with a hook structure integrated into the crown design at the initial stage to allow for a pull-out test. All crowns were designed using CAD software (DentalCAD V2.3, Matera, Exocad) with the same morphological characteristics for each group. Each molar crown was modeled with a crown height of 10 mm and a buccolingual and mesiodistal width of 10 mm; hook dimensions measuring 7 mm in height and 5 mm in buccolingual and mesiodistal dimensions were on the approximal surfaces to enable the pull-out test. The completed restorations were fabricated from zirconia blocks (Upcera® Functional Explore, Shenzhen Upcera Dental Technology, China). The cement gap was determined to be 30 μm (micrometers) (13). For each group, 15 monolithic zirconia blocks (Upcera® Functional Explore, Shenzhen Upcera Dental Technology, China) were milled on a milling machine (Redon, Hybrid Dental CNC; Redon Technology). After milling the monolithic zirconia material, all crown samples were sintered (Redon Rapid, Redon Technology, Istanbul, Turkey) using a multi-stage temperature program to achieve microstructural stability and optimal density, as this process requires firing. The samples were heated from 30°C to 1150°C at a rate of 8°C/min and held for 30 minutes, then raised to 1300°C at a rate of 2°C/min to initiate densification. The temperature was then raised to 1480°C at a rate of 4°C/min and held for 2 hours to complete the main sintering. Subsequently, the temperature was lowered from 1480°C to 800°C at a rate of −8°C/min, and cooling below 800°C was carried out naturally. This controlled process ensured homogeneous densification of the zirconium, elimination of internal stresses, and prevention of crack formation. The cementation surfaces of crowns to be cemented onto Ti-base abutments were treated with 50 μm aluminum oxide (Al_2O_3) particles (Akrodent Akroxide White Sand, Koca Kimya ve Dental LTD. ŞTİ., Ankara, Turkey) using an air blasting device (Twin-Pen Sand Blasting Machine with Drawer, JG-218, China) at a distance of 10 mm and a pressure of 2.0 bar for 10 seconds. This procedure was not applied to Ti-base abutments. The specimens were ultrasonically washed with distilled water for 180 seconds, cleaned with 96% ethanol, and air-dried.

Table 1. Model description

Model Number	Angle	Ti-Base Length
Model 1	0°	3.5 mm
Model 2	0°	5.5 mm
Model 3	15°	3.5 mm
Model 4	15°	5.5 mm

The specimens were then bonded according to the manufacturer's instructions (Ceramic Bond, VOCO, Cuxhaven, Germany); the bond applied to the Ti-base abutment surface and inner surface of the crown was allowed to react for 60 seconds and carefully dried with air spray. The screw holes of the Ti-base abutments were sealed with Teflon tape to prevent cement leakage. A thin layer of dual-cure resin cement Bifix® Hybrid Abutment (VOCO, Cuxhaven, Germany) was applied directly from the mixing syringe to the bonding surfaces of the Ti-base abutments and monolithic zirconia copings. After the cement was mixed and the crowns were placed on the abutments, a weight of approximately 50 N (5 kg) was used for standardization for 10 minutes until the cement hardened (15). Excess material overflowing from the collar area and screw hole was cleaned with a microbrush. With a 1.000 mW/cm² light output LED light device (RIXI, Foshan, China), all surfaces were polymerized for 10

Figure 2. Cementation preparation

seconds as close as possible to the light device. After 10 seconds of polymerization, the overflowing cements were eliminated again, and then polymerization was performed with the light device for another 10 seconds, including all surfaces. Each surface was subjected to polymerization for a total of 20 seconds. (Figure 2) After completing the polymerization process, the Teflon tape in the screw hole was removed.

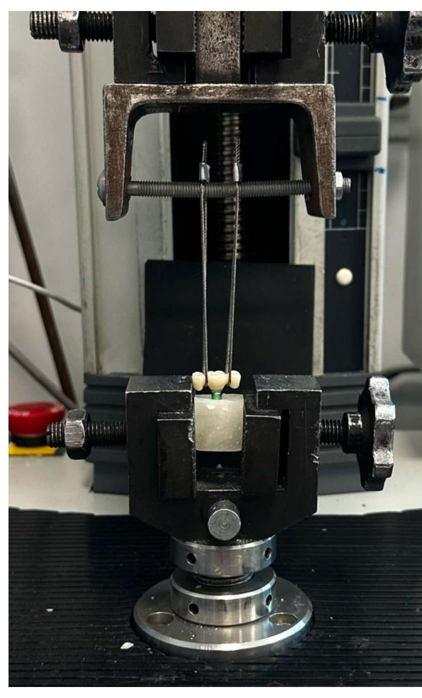

Figure 3. Tensile testing of specimens on a universal testing machine (Lloyd-LRX; Lloyd Instruments, Fareham, UK)

All samples that underwent the cementation process were placed in a thermal cycling device (Thermocycler – SD Mechatronik, Germany) to simulate the effects that oral temperature changes could expose them to over a one-year period. A thermal ageing protocol of 10.000 cycles between 5°C and 55°C was applied. During this process, each sample was held in a 5°C bath for 30 seconds, followed by 30 seconds in a 55°C bath; the transition time between the two baths was set at 15 seconds. The specimens were stored in a moist environment at 37 °C for 24 hours before testing (17). Ti-base abutments and zirconium crowns were embedded in acrylic, and the specimens were then fixed under a universal testing machine. The crowns, which have two pontic-shaped protrusions at their approximations designed to apply tensile force, were connected to the upper part of the machine by passing a stainless steel wire through them. The stainless steel wire was attached to the apparatus on the upper arm of the testing device, which would apply the tensile force, thus reinforcing the vertical orientation of the crown. Pull-out testing (Figure 3) was performed on a universal testing machine (Lloyd-LRX; Lloyd Instruments, Fareham, UK) at a speed of 1 mm/min until cementation failure or screw breakage occurred. (Figure 4) A load cell of 5000 N was used in the instrument and fixed to the instrument with a holding area to place the specimen. The maximum force used during cementation failure was recorded in newtons (N).

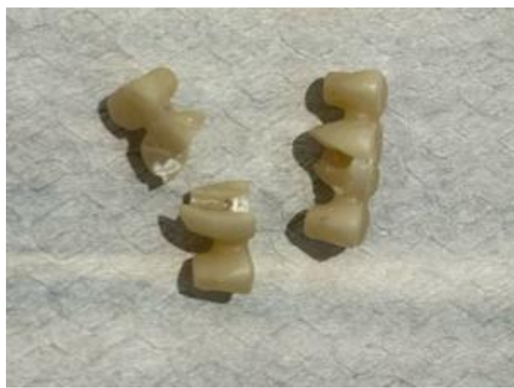

Figure 4. Examples of failures occurring after the tensile test

Statistical analysis

The data obtained in this study were analyzed using the SPSS 22 statistical software package. Although the variable exhibited a normal distribution, the assumption of homogeneity of variances was not met, as indicated by Levene's test ($p < 0.05$). Due to this violation, comparisons of the mean Maximum Load (N) values among the four groups were performed using Welch's Analysis of Variance (Welch ANOVA), which is robust to unequal variances. A statistically significant Welch ANOVA result indicated that there was a significant difference in the mean load bearing capacity among at least two of the groups. To identify which specific group pairs accounted for these differences, Tamhane's T2 post-hoc test—appropriate when the homogeneity of variances

June 2026 27(2):210-218

Meandros Medical and Dental Journal
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Table 2. Descriptive statistics and Welch ANOVA results for maximum load (N)

	Descriptives								Anova	
	N	**Mean**	**Std. Deviation**	**Std. Error**	**CI Lower Bound**	**CI Upper Bound**	**Min**	**Max**	**Welch**	**P**
Model 1	15	306.0221	113.24984	29.24098	243.3064	368.7378	173.35	513.51		
Model 2	15	736.2439	145.59202	37.59170	655.6177	816.8701	482.04	991.53		
Model 3	15	267.1030	76.00908	19.62546	225.0106	309.1955	142.90	398.53	86.08	0.0001
Model 4	15	969.6590	203.07619	52.43405	857.1992	1082.1189	533.85	1254.62		
Total	60	569.7570	328.49127	42.40804	484.8987	654.6153	142.90	1254.62		

Maximum load (N) was defined as the dependent variable. N: sample size; Std. Deviation: standard deviation; Std. Error: standard error; CI: confidence interval. Welch ANOVA showed a statistically significant difference among the groups ($p < 0.0001$).

assumption is violated—was conducted. For all analyses, the significance level was set at $\alpha = 0.05$. Results with $p < 0.05$ were interpreted as statistically significant, whereas $p > 0.05$ indicated non-significant differences.

RESULTS

The pull-out force values are presented in Table 2. The assumption of normality was confirmed for all groups using the Shapiro–Wilk test ($p > 0.05$). However, homogeneity of variances was not satisfied (Levene's test, $p < 0.05$). Accordingly, a Welch one-way analysis of variance was performed to assess whether significant differences existed in maximum load (N) among the four experimental models. The Welch ANOVA demonstrated a statistically significant difference in mean maximum load among the groups (Welch $F(3, 29.49) = 86.08$, $p < 0.0001$), indicating that at least one group mean differed from the others. Because the assumption of equal variances was violated, multiple comparisons were conducted using the Tamhane T2 post-hoc test (Table 3). The post-hoc analysis revealed statistically significant differences between all group pairs ($p < 0.05$), except between Model 1 (0°, 3.5-mm Ti-base) and Model 3 (15°, 3.5-mm Ti-base), for which no statistically significant difference was observed (mean difference = 38.92 N; 95% CI: −98.7 to 176.5; $p = 0.862$). Model 4 (15°, 5.5-mm Ti-base) exhibited the highest mean maximum load (969.66 N; 95% CI: 857.20–1082.12), followed by Model 2 (0°, 5.5-mm Ti-base) (736.24 N; 95% CI: 655.62–816.87). The lowest mean value was recorded in Model 3 (15°, 3.5-mm Ti-base) (267.10 N; 95% CI: 225.01–309.20) (Table 2; Figure 5). Overall, groups restored with 5.5 mm Ti-bases demonstrated substantially higher pull-out forces than those restored with 3.5 mm Ti-bases, corresponding to an approximately three-fold increase in mean maximum load values. The distribution of maximum load values and statistically homogeneous subgroups based on the Tamhane T2 test are illustrated in Figure 5. Because a one-way analytical model was applied, the independent main effects of Ti-base height and implant angle, as well as their potential interaction, could not be formally evaluated. Despite the use of a one-way analytical approach, the large and consistent differences in maximum load values among the predefined experimental groups support the robustness of the primary results.

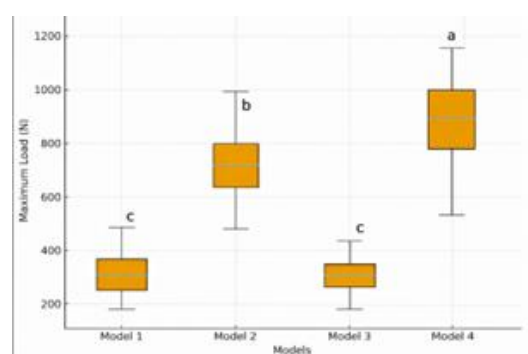

Figure 5. Maximum Load Capacity by Groups (Boxplot) (Boxplot of maximum load (N) values. Lowercase letters (a, b, c) indicate statistically homogeneous groups based on the Tamhane T2 post-hoc test; groups sharing the same letter are not significantly different ($p < 0.05$).)

Table 3. Post-hoc Analysis (Tamhane T2) results

(I) Group	(J) Group	Mean Difference (I-J)	p	Lower Bound	Upper Bound
Model 1	Model 2	-430.22183*	0.000	-567.8	-292.6
Model 1	Model 3	38.91904	0.862	-98.7	176.5
Model 1	Model 4	-663.63697*	0.000	-801.3	-526.0
Model 2	Model 3	469.14088*	0.000	331.5	606.8
Model 2	Model 4	-233.41513*	0.000	-371.0	-95.8
Model 3	Model 4	-702.55601*	0.000	-840.2	-564.9

Dependent variable: Maximum load (N). Tamhane T2 post-hoc test was used for multiple comparisons. Mean difference (I-J) represents the difference between group means. CI: confidence interval. $p < 0.05$ indicates a statistically significant difference.

DISCUSSION

This study was conducted to evaluate the tensile load applied using different Ti-based abutment heights on implants placed at a straight and a 15-degree angle. Two hypotheses were evaluated in this study. The first null hypothesis was partially supported, as no significant difference in crown retention was observed among the 3.5 mm abutment groups, whereas a significant difference was detected among the 5.5 mm abutment groups. The second null hypothesis was not supported, since abutment height was found to have a significant effect on maximum load capacity. For Ti-base monolithic zirconia restorations on straight or angled implants, a Ti-base height of 5.5 mm significantly increased crown retention, whereas a height of 3.5 mm did not produce a significant difference between angle groups. Thus, Ti-base height had a significant effect on maximum load capacity in crown retention. Although implant angulation did not influence maximum load capacity in the 3.5 mm groups, it did significantly affect retention in the 5.5-mm groups. To mimic intraoral conditions, the specimens were subjected to 10,000 thermocycles between 5°C and 55°C, similar to a previous study (18).

In dentistry, the use of abutments whose geometries can be stored in the system with CAD/CAM technology provides the possibility of successful oral rehabilitation (17). Selecting the appropriate abutment for the case can help prevent complications that may occur in implant-supported restorations, increase retention, and achieve more aesthetic results (19).

Ti-base abutments combine the advantages of prefabricated and custom abutments; the titanium implant-abutment connection ensures precise fit and enhanced durability while also allowing for the formation of the emergence profile. The cementation procedure performed in the laboratory is a procedure that allows for the removal of cement, thereby reducing soft tissue reactions (17).

Retention loss is a disadvantage for cement-retained restorations, and studies have reported a retention loss rate ranging from 4.1% to 5.5% after 5 years (20). Nguyen et al. reported that the retention of zirconia restorations bonded to Ti-base abutment is influenced by several parameters beyond abutment height, including surface treatment, cement type, total occlusal convergence, surface area, surface roughness, and auxiliary retentive features. They also highlighted that abutment geometry and design play a critical role in enhancing retention (13). Previous studies have yielded conflicting results regarding Ti-base abutment height and retention level (15,17). The scientific literature evaluating the effect of monolithic zirconia crown restorations adhering to Ti-base abutments is insufficient. Therefore, the present study investigated the effect of Ti-base abutment height and implant angle on retention. One study showed that longer abutments provide a larger surface area than shorter abutments, resulting in higher maximum load values regardless of the prosthetic material used (21). The findings of the present study are consistent with those results. Regardless of the angular difference, the average maximum load value was 736.2439 N in Model 2, where the Ti-base height was 5.5 mm, while it was 306.0221 N in Model 1, where the Ti-base height was 3.5 mm.

In their 2023 study, Alseddiek et al. used two different Ti-base support heights (7 mm vs. 4 mm), similar to the present study, and measured the retention of the crowns using a pull-out test. The average maximum load in the long Ti-base (7 mm) abutment group was 434.7 N, while the average maximum load in the short Ti-base (4 mm) abutment group was 231.1 N. Although the Ti-base support heights used in present study were 3.5 mm and 5.5 mm, the average maximum load values were 306.0221 N for the short (3.5 mm) Ti-base group and 736.2439 N for the long (5.5 mm) Ti-base group. This situation may be due to differences in the cement gap of the zirconium crowns used in the studies or differences in the cementation protocol. (14)

Implants placed at an angle due to bone insufficiency or surgical errors in implant placement can result in abutments positioned at an angle between 5˚ and 30˚ within the oral cavity. Angled abutments are reported to have a high survival rate (16). An angulated design was included in the current study to mimic the retention success of angle implants. Analogs were embedded in acrylic blocks at angles of 0° and 15°.

Studies investigating the fracture resistance and performance of zirconia implant abutments with different inclinations are available in the literature. It has been reported that an implant–abutment inclination of 15° provides significantly higher fracture resistance than 0° or 25° (22). Bonyatpour et al. (2023) evaluated the effect of different implant angles (0°, 15°, and 25°) on the fracture resistance of monolithic zirconia restorations and noted that the 15° angled implant group offered significantly higher fracture resistance compared to the straight (0°) implant. However, no additional advantage was observed for the 25° angle compared to the 15° angle (16). This

suggests that slightly angled implant placements may be more suitable from a restorative perspective. In the current study, based on this article (16), 0° and 15° angle configurations were used, and similarly, it was found that the angle configuration affected crown retention.

In the current study, when comparing Model 2 and Model 4 with the same Ti-base support length, it was observed that the angle factor significantly affected retention. However, when only the angle configuration was changed in Model 1 and Model 3, which have a Ti-base length of 3.5 mm, no significant difference was found in the results. The average maximum load value in Model 3, which has a 15° angle configuration, is 267.1030 N, and this value is the lowest among all other groups. When evaluating the pull-out test results of Ti-base monolithic zirconia restorations, values remaining above the recommended reference level (~159 N) and falling within the range commonly reported in the literature were interpreted as clinically acceptable (23). The Model 3 group samples, which had the lowest maximum load values among the study groups, were also clinically acceptable.

The available studies indicate that implant angle has an important effect on restorative success (16,24). They suggest that 15° angulated implants can provide both mechanical and biological advantages, whereas the clinical benefits of angulations of 25° or more may be limited. Therefore, careful evaluation of the angle in implant planning is critical for both restoration retention and long-term success. From a clinical decision-making perspective, these findings suggest that in posterior regions where angled implant placement is required due to anatomical constraints, prioritizing Ti-base abutment height selection may be more critical for achieving adequate retention than implant angulation alone.

Another study supporting the effect of implant design on fracture resistance evaluated the maximum load capacity of restorations made from different materials using 4-mm and 7-mm Ti-base abutments and emphasized that abutment height significantly affects retention strength (14). Studies evaluating the effects of Ti-base abutment height and surface treatments on restoration retention have reported that increasing Ti-base height directly improves retention and that abutments with heights of 4.5 mm and 5.5 mm provide significantly higher retention than those with a height of 3.5 mm (13,17). These findings are similar to the results of the present study.

Some studies have concluded that retention is not significantly affected when the Ti-base abutment height is altered, which contradicts the current study and most studies in the literature (15,25). The reasons for the contradiction between the results of these studies and the results of the current study may include the difference in height between Ti-base abutments and the absence of the angle factor.

One of the most important limitations of the study is that it is an in vitro study. The limited interocclusal distance and mouth opening in intraoral conditions, as well as factors such as the condition of the contact teeth, play a critical role in selecting the implant angle and abutment height. The tensile test used in the study cannot simulate the forces acting on the restoration from different directions, as occurs in the oral environment. Furthermore, the same surface treatment and cementation procedure were applied to all specimens. Another limitation is that the failures mentioned in the current study are not classified. In subsequent studies, it is necessary to use a chewing simulator to simulate the oral environment more accurately, apply different cementation protocols and surface treatments, and conduct the study in the intraoral environment, taking into account the amount of interocclusal distance, adjacent teeth, and anatomical structures.

CONCLUSION

Within the limitations of this study, the following conclusions have been drawn:
1. Abutment height affected retention in both straight and angled implants.
2. Among the groups where the implant was placed at an angle, the group with 5.5 mm abutment height was the one where retention was affected.
3. The pull-out test results for all sample groups were above the clinically acceptable reference level (~159 N) (23).
Based on the results of the current study, it is considered that Ti-base abutments with heights of 3.5 mm and 5.5 mm are clinically suitable for use.
In fixed monolithic zirconia restoration treatments on implants, selecting the longest Ti-base abutment height, considering the Ti-base abutments used with angled or straight implants and the prosthetic area, can minimize the risk of restoration dislodgement.

Acknowledgments

The authors extend their sincere thanks to all individuals and institutions that contributed to this study, particularly the laboratory team that provided technical support in the CAD/CAM manufacturing processes of zirconia crowns and the conduct of mechanical tests.

Authorship contributions

C.E.K, L.K, M.A.K designed the study and developed the concept. C.E.K conducted the literature review, data collection, and wrote the manuscript. H.G analyzed the data. C.E.K and H.G performed the study and interpreted the data. C.E.K prepared the first draft of the article, and H.G, L.K, and M.A.K edited and revised the article. All authors read and approved the final version.

Data availibity statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of competing interest

The authors declare no competing interests.

Ethics

This study was conducted in accordance with the ethical principles of the World Medical Association's Declaration of Helsinki. The study does not involve any human or animal experiments. Therefore, ethical committee approval is not required.

Funding

No financial support was received from any institution or organisation for this study.

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