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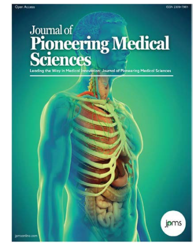

# Influence of Various Implant-Abutment Connection Designs on Microleakage and Bacterial Penetration


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**Abstract** **Objectives:** The connection between implant and abutment establishes essential conditions for lasting success of dental implant therapy. Bacterial colonization at the implant-abutment connection causes microleakage which subsequently leads to peri-implant diseases as well as eventual implant failure. The Morse taper together with internal hexagon and external hexagon represent three implant-abutment connection designs which seek to decrease bacterial penetration. The present study examines how variations in implant-abutment connections affect both microleakage and bacterial infiltration between components. **Methods:** This *in vitro* research examined 60 titanium dental implants through three distinct connection design categories consisting of Morse taper with 20 units and internal hexagon with 20 units and external hexagon with 20 units. A bacterial exposure with Streptococcus mutans occurred on each implant-abutment unit before placing them in a 37°C environment during a seven-day period. Laboratory examination of bacterial penetration included RT-PCR tests and evaluation of bacterial cultures. A spectrophotometric analysis of dye penetration technique was employed to measure microleakage between groups. The statistical analysis employed one-way ANOVA for data assessment while post-hoc Tukey’s test provided supplemental evaluations at a p value below 0.05. **Results:** The Morse taper connection group demonstrated better microleakage resistance through its 0.25±0.05 mm readings when compared to the 0.67±0.08 mm readings from internal hexagon and 1.12±0.10 mm readings from external hexagon groups ($p<0.05$). Bacterial penetration occurred in 10% of Morse taper implants whereas 45% of internal hexagon implants presented bacterial penetration and 75% of external hexagon implants showed bacterial penetration. The Morse taper connection provided advanced sealing ability that reduced both microleakage and bacterial passage through the connection. **Conclusion:** Design specifications for implant-abutment connections determine how well bacterial agents and fluid can pass through the connection. Morse taper connections show enhanced sealing capabilities which lowers the chance of bacterial infections during the procedure. Clinical application of Morse taper implants should be favored because research shows they help extend implant life and decrease peri-implant bacterial infections. The research demonstrates that Morse taper connections decrease peri-implant diseases effectively because they block bacterial penetration. The clinical use of Morse taper implants should be considered when sustaining implant longevity together with controlling infection rate is essential.



**Key Words** Implant-abutment connection, Microleakage, Bacterial penetration, Morse taper, Internal hexagon, External hexagon, Peri-implant disease


## INTRODUCTION

The dental implant procedure functions as a widely recognized teeth replacement method which provides better oral functionality and better appearance options. Implant longevity depends heavily on implant-abutment connections since these elements maintain the structure and block bacterial entry into the system [1]. Phageflow of bacteria at the implant-abutment interface leads to peri-implant inflammation as well as bone loss that culminates in implant failure [2,3].

Research teams have created numerous implant-abutment connection types to achieve better sealing functions and reduced microleakage. Research shows that the Morse taper connection delivers excellent bacterial sealing through its cone shape that locks together better and creates minimal microgap measurements [4,5]. Internal and external hexagonal connections show higher microleakage potential because both their structural design and their tendency to move from abutment manipulation [6,7]. Micrograps found in these systems serve as bacterial reservoirs that lead to the development of peri-implant diseases according to research studies [8,9].

The implant-abutment interface bacterial infiltration can be evaluated through three *in vitro* techniques which include bacterial culture and real-time polymerase chain reaction (RT-PCR) and spectrophotometric dye penetration analysis [10,11]. The tested methods allow researchers to measure how well various connection approaches prevent bacterial infiltration into implant systems. The identification of design-to-bacterial microleakage relationships in implant-abutment connections provides essential data for developing implant success-rate enhancing and peri-implant complication minimizing methods.

The research examines how different implant-abutment interfaces including Morse taper along with internal hexagon and external hexagon affect bacterial penetration and microleakage formation. The examination of these systems seeks to identify the most optimal bacterial sealing properties which will enhance the long-term achievement of dental implants. Medically speaking bacterial microleakage at the implant-abutment junction requires reduction because it extends implant durability and fights peri-implantitis particularly in high-risk patient groups which include diabetic and smoking individuals. The study boundaries excluded analysis of recent surface treatment innovations including nanostructured coatings and antibacterial modifications that demonstrate promise in improved implant integration and bacterial resistance. This research examined the microleakage levels and bacterial penetration within three implant-abutment connection types namely Morse taper, internal hexagon and external hexagon. The experiment analyzed microleakage through spectrophotometric dye assessment as its main outcome and assessed bacterial penetration by combining RT-PCR and CFU quantification techniques. The Morse taper connection should show better sealing abilities than hexagonal devices thus promoting longer implant survival paired with lesser peri-implant tissue disorders.

## METHODS

A laboratory investigation examined microleakage alongside bacterial penetration in implant-abutment connection designs under test conditions. A research involving three implant-abutment connection types used 60 titanium dental implants that were divided into Morse taper (n = 20), internal hexagon (n = 20), and external hexagon (n = 20). All implants originated from one producer to guarantee a consistent product material composition together with surface characteristics. Sample size estimation was performed using G*Power software with an effect size of 0.8, power of 0.9, and $\alpha = 0.05$, which determined a minimum of 18 samples per group. We included 20 samples per group to account for potential losses. Group assignment was randomized using a computer-generated sequence to minimize allocation bias. Surface roughness of all implants was standardized and verified using profilometry prior to grouping to ensure comparability across all samples.

Each implant-abutment combination received ultrasonic distilled water treatment lasting five minutes before undergoing 15-minute sterility-enhancing autoclaving at 121°C. The abutment installation onto implants occurred according to manufacture guidelines through the application of a calibrated torque wrench. The specimens spent 24 hours at 37°C under artificial saliva solution for intraoral environment simulation. Sterility was ensured by maintaining aseptic conditions throughout the experiment. All handling of implants and bacterial inoculation procedures were performed in a Class II biosafety cabinet under sterile conditions using autoclaved instruments and consumables.

A 0.5 McFarland concentration of Streptococcus mutans bacteria in brain-heart infusion broth served as the reference standard to prepare 10 μL bacterial suspension which received injection into implant-abutment interfaces through a micropipette. Bacterial penetration and biofilm formation was allowed by the samples through an incubation cycle at 37°C within an anaerobic chamber for seven days. To reduce methodological error, all RT-PCR procedures were carried out using validated commercial kits with internal controls. Spectrophotometric readings were conducted in triplicate to ensure reproducibility, and operator calibration was done to minimize intra-observer variability.

The evaluation of microleakage occurred through spectrophotometric dye penetration measurements. The researchers placed each implant-abutment combination inside 1% methylene blue dye solution for 48 hours. The implants were cut in half after rinsing in distilled water so the microscope could measure the amount of dye that penetrated through stereomicroscopic observation. The measurement of microleakage occurred in units of millimeters.

Calculations using RT-PCR and bacterial cultures determined whether bacteria had penetrated the implant-abutment connection. The inner parts of implants underwent DNA extraction through a commercial bacterial DNA extraction kit before S. mutans-specific primer-based amplification procedures for RT-PCR analysis. BHI agar plates with 24 hours (37°C) incubation following paper point placement into sterile implant-abutment interface allowed counting of colony-forming units (CFUs).

The researchers conducted their analysis through SPSS (version 26). The analysis included One-way ANOVA to evaluate microleakage data between the three groups. Post-hoc Tukey's test determined specific inter-group pair comparisons. A chi-square analysis determined whether bacteria penetrated through the list examined areas. All reported data reached statistical significance with a p value of less than 0.05.

## RESULTS

### Microleakage Analysis

Table 1 contains the recorded mean microleakage values from the three implant-abutment connection designs. The Morse taper connection achieved the minimum microleakage value of 0.25±0.05 mm compared to 0.67±0.08 mm for the internal hexagon and 1.12±0.10 mm for the external hexagon group. Research findings demonstrated that the three experimental groups presented different microleakage values since statistical significance exceeded 0.05 ($p<0.05$). Patient treatment benefits from the Morse taper connection as it produces better sealing and smaller microleakage than other implant design methods (Table 1).

The significant difference in microleakage values suggests that Morse taper provides a more hermetic seal at the implant-abutment interface, which may directly translate into improved clinical outcomes by minimizing early bacterial colonization.

### Bacterial Penetration

The bacterial penetration rates for each implant-abutment connection type are summarized in Table 2. Bacterial infiltration was detected in 10% of the Morse taper group, 45% of the internal hexagon group, and 75% of the external hexagon group ($p<0.05$). These results suggest that the Morse taper connection is more effective in preventing bacterial contamination compared to the hexagonal connection types (Table 2).

These findings have important clinical implications, particularly in reducing the incidence of peri-implant infections in susceptible patient populations by selecting implant systems with lower microbial penetration.

### Bacterial Load Quantification

The bacterial load inside the implant-abutment interface was assessed using CFU counting and RT-PCR analysis (Table 3). The Morse taper connection showed the lowest bacterial load ($2.1\times10^3$ CFU/mL), while the internal and external hexagon connections exhibited significantly higher bacterial contamination ($5.8\times10^3$ CFU/mL and $9.4\times10^3$ CFU/mL, respectively). These differences were statistically significant ($p<0.05$).

The lower bacterial load observed in the Morse taper group supports its effectiveness in resisting biofilm formation, a key contributor to implant complications such as peri-implant mucositis and peri-implantitis.

### Statistical Findings

One-way ANOVA analysis revealed a significant difference in microleakage, bacterial penetration, and bacterial load across all groups ($p<0.05$). Post-hoc Tukey's test confirmed that the Morse taper group had significantly lower microleakage and bacterial penetration compared to the other groups ($p<0.05$).

These results highlight the superior bacterial sealing ability of the Morse taper connection, which could contribute to reducing the risk of peri-implant complications.

Table 1: Mean Microleakage (mm) in Different Implant-Abutment Connection Designs

| Implant-Abutment Connection | Mean Microleakage (mm)±SD |
|---|---|
| Morse Taper | 0.25±0.05 |
| Internal Hexagon | 0.67±0.08 |
| External Hexagon | 1.12±0.10 |
| p-value | < 0.05 |

Table 2: Bacterial Penetration Rate in Different Implant-Abutment Connection Designs

| Implant-Abutment Connection | Bacterial Penetration (%) |
|---|---|
| Morse Taper | 10% |
| Internal Hexagon | 45% |
| External Hexagon | 75% |
| p-value | < 0.05 |

Table 3: Bacterial Load (CFU/mL) in Different Implant-Abutment Connection Designs

| Implant-Abutment Connection | Bacterial Load (CFU/mL)±SD |
|---|---|
| Morse Taper | $2.1\times10^3\pm0.5\times10^3$ |
| Internal Hexagon | $5.8\times10^3\pm1.2\times10^3$ |
| External Hexagon | $9.4\times10^3\pm1.8\times10^3$ |
| p-value | < 0.05 |

## DISCUSSION

Designs of implant-abutment connections serve dual functions by establishing implant stability and blocking bacterial penetration that leads to peri-implant diseases. This research study confirmed that Morse taper connections perform better than internal and external hexagonal connections for sealing purposes when analyzing implant-abutment microleakage and bacterial penetration. Studies in the field proved that conical implant-abutment connections decrease bacterial penetration because of their mechanical locking ability and self-retention system [1,2]. Our findings reinforce the notion that mechanical design, particularly conical locking systems like Morse taper, plays a pivotal role in reducing microleakage and microbial ingress under static *in vitro* conditions.

The amount of leakage that occurs between an implant and its abutment plays a fundamental role in causing peri-implant tissue inflammation. This research demonstrated that the Morse taper connection produced the least microleakage but the external hexagon connection indicated the highest microleakage results. Studies have established that Morse taper interfaces create a stronger seal preventing microorganisms from penetrating into the interface zone [3,4]. The susceptibility to develop microleakage is higher in external hexagon connections since they experience microgaps which cannot withstand occlusal loading forces [5,6].

The success rate of dental implants depends heavily on how well bacteria can penetrate their structure. The research findings demonstrated that bacterial infiltration levels were markedly lower in Morse taper connections relative to both internal hexagon and external hexagon connections. Past research has confirmed that Morse taper connections exhibit lower bacterial counts because their smaller microgap size makes it harder for microorganisms to invade [7,8]. The internal and external hexagon connections showed increased bacterial penetration rates that might lead to peri-implantitis and implant failure according to research findings [9,10].

Bacterial load tests confirm these results by measuring lower bacterial levels in Morse taper connections than in the other tested methods. Available literature supports the conclusion that bacterial leakage decreases when using conical connections compared to hexagonal connections [11,12]. The Morse taper connection blocks bacterial contamination through its friction-fit concept that reduces bacterial accumulation sites [13].

Several scientific studies demonstrate how mechanical factors determine the extent of bacterial leakage that develops between implant-abutment joints. Researchers have shown that hexagonal connection interfaces produce movement that allows bacteria to penetrate when stress is applied in functionally loaded conditions [14]. Morse taper connections present better mechanical stability over other systems by lowering the threat of bacterial microleakage and implant complications [15]. The method of abutment tightening plays a crucial role in developing microleakage between components. Calibrated wrenches delivered torque according to manufacturer guidelines yet actual microgap alterations might occur from minor torque-related changes. The leakage in hexagonal systems tends to get worse due to improper prosthetic fit and mechanical instability that occurs when patients perform chewing functions. The explored variables must be included in upcoming dynamic testing protocols because they mirror essential clinic aspects although not employed during this study.

The testing environment used outside the body fails to duplicate all aspects of the oral ecosystem since it does not include pH variations or masticatory stress or temperature changes. The findings from this study could be limited in their practical clinical application due to the absence of fatigue loading as well as real-time prosthetic use. Studies must include the essential variable components in future research designs along with complete analysis of long-term structural change *in vivo*.

### Future Recommendations

Clinical studies are necessary to evaluate how Morse taper implants perform under cyclic loading and in patients with compromised immunity, diabetes, or poor oral hygiene. Moreover, investigations into the effect of torque variability, abutment fit, and advanced antibacterial coatings on microleakage should be pursued to enhance our understanding of connection design optimization.

## CONCLUSIONS

The research data shows that implant-abutment connections designed with Morse taper exhibit better performance against microleakage and bacterial penetration. The clinical implementation of Morse taper designs now has evidence showing their effectiveness to prevent peri-implantitis and promote extended implant service. The use of Morse taper systems stands as an excellent choice for clinical applications which combine elevated risk of infection with extended prosthesis life requirements. Clinical experiments should be performed with dynamic loading in combination with varied patient groups including smokers and diabetics to validate the *in vitro* research outcomes.

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