Cumhuriyet Dental Journal, 28(3): 412-418, 2025
DOI: https://doi.org/10.7126/cumudj.1720354

Cumhuriyet Dental Journal

| cdj.cumhuriyet.edu.tr | Founded: 1998 Available online, ISSN: 1302-5805 Publisher: Sivas Cumhuriyet Üniversitesi

Comparative Micro-CT Evaluation of Ball Attachment Compatibility in Implant and Analog Connections Using Hand Driver and Torque Wrench

Ayben Şentürk[1,a,*], Mert Ocak[2,b], Bora Akat[1,c]

[1]*Department of Prosthodontics, Faculty of Dentistry, Ankara University, Ankara, Türkiye.*
[2]*Department of Basic Medical Science—Anatomy, Faculty of Dentistry, Ankara University, Ankara, Türkiye.*
**Corresponding author*

Research Article

History

Received: 15/06/2025
Accepted: 22/07/2025

ABSTRACT

Objectives: This study aimed to evaluate the effect of different tightening tools—a hand driver and a torque wrench—on the connection interface adaptation of ball attachments, at both the implant and analog levels, using micro-computed tomography (micro-CT).
Materials and Methods: Twenty implants and twenty analogs from two implant systems, BioInfinity (Turkey) and Dentis (Korea), were used, and a total of 40 ball attachments were evaluated. Each attachment was tightened using both a hand driver and a torque wrench at implant and analog levels. All samples were scanned using high-resolution micro-computed tomography (micro-CT). To assess the compatibility of the implant/analog–ball attachment connections, linear measurements at the interface were performed. Statistical analysis included one-way ANOVA, Tukey's HSD test, and independent samples t-test, with significance set at $p < 0.05$.
Results: In the BioInfinity system, statistically significant differences were found both between implant and analog connections and between the two tightening methods ($p < 0.05$), with hand tightening often resulting in deeper seating. Conversely, in the Dentis system, no significant difference was observed between implant and analog interfaces ($p > 0.05$), although the tightening method still had a significant effect ($p < 0.05$). Inter-system comparisons showed no statistically significant differences between the two systems regarding the effect of tightening tools ($p > 0.05$).
Conclusions: The results of this in vitro study showed that the connection interface adaptation of ball attachments varied depending on the implant system and the tightening method. In the BioInfinity system, both the type of connection (implant vs. analog) and the tightening method (hand driver vs. torque wrench) significantly affected the linear discrepancy. In contrast, in the Dentis system, only the tightening method showed a significant effect, while the connection type did not.

Keywords: Ball attachments, hand driver, torque wrench, micro-ct

İmplant Anahtarı ve Tork Anahtarı Kullanılarak İmplant ve Analog Bağlantılarında Ball Ataşman Uyumluluğunun Karşılaştırmalı Mikro-CT Değerlendirmesi

Araştırma Makalesi

Süreç

Geliş: 15/06/2025
Kabul: 22/07/2025

ÖZ

Amaç: Bu çalışma, implant destekli overdenture sistemlerinde kullanılan ball ataşmanların bağlantı yüzeyi adaptasyonuna, farklı vidalama araçlarının—implant anahtarı ve tork anahtarı—etkisini, hem implant hem de analog düzeylerinde, mikro-bilgisayarlı tomografi (micro-CT) kullanarak değerlendirmeyi amaçlamıştır.
Gereç ve Yöntemler: Yirmi implant ve yirmi analog, iki implant sisteminden, BioInfinity (Türkiye) ve Dentis (Kore), kullanıldı ve toplamda 40 adet top bağlantı (ball attachment) değerlendirildi. Her ataşman, hem implant hem de analog düzeylerinde, hem implant anahtarı hem de tork anahtarı ile vidalanmıştır. Tüm örnekler yüksek çözünürlüklü mikro-CT ile taranmıştır. İmplant/analog ile ball ataşman bağlantılarının uyumluluğunu değerlendirmek amacıyla, bağlantı yüzeyinde lineer ölçümler yapılmıştır. İstatistiksel analizde tek yönlü ANOVA, Tukey'nin HSD testi ve bağımsız örneklem t-testi kullanılmış; anlamlılık düzeyi $p < 0,05$ olarak belirlenmiştir.
Bulgular: BioInfinity sisteminde, hem implant ve analog bağlantıları arasında hem de iki farklı vidalama yöntemi arasında istatistiksel olarak anlamlı farklar bulunmuştur ($p < 0,05$); el ile vidalama genellikle daha derin oturumla sonuçlanmıştır. Buna karşılık, Dentis sisteminde implant ve analog bağlantıları arasında anlamlı bir fark gözlenmemiştir ($p>0.05$); ancak vidalama yönteminin yine de anlamlı bir etkisi olduğu belirlenmiştir ($p < 0,05$). Sistemler arası karşılaştırmalarda, vidalama aracının etkisi açısından istatistiksel olarak anlamlı bir fark bulunmamıştır ($p > 0.05$).
Sonuçlar: Bu in vitro çalışmanın sonuçları, ball ataçmanların bağlantı yüzeyi adaptasyonunun kullanılan implant sistemi ve sıkma yöntemine bağlı olarak değiştiğini göstermiştir. BioInfinity sisteminde, hem bağlantı tipi (implant vs. analog) hem de sıkma yöntemi (el tipi sıkıcı vs. tork anahtarı) lineer farklılık üzerinde anlamlı bir etkiye sahipti. Buna karşılık, Dentis sisteminde yalnızca sıkma yöntemi anlamlı bir etki gösterirken, bağlantı tipi açısından anlamlı bir fark gözlemlenmemiştir.

Anahtar Kelimeler: Ball ataşmanlar, el tornavidası, tork anahtarı, mikro-CT

[a] *ayben_senturk@windowslive.com* *0000-0002-1096-4810*
[b] *mocak@ankara.edu.tr* *0000-0001-6832-6208*
[c] *bakat@ankara.edu.tr* *0000-0003-2928-2526*

How to Cite: Şentürk A, Ocak M, Akat B. (2025) Comparative Micro-CT Evaluation Of Ball Attachment Compatibility In Implant And Analog Connections Using Hand Driver And Torque Wrench, Cumhuriyet Dental Journal, 28(3): 412-418.

Introduction

The use of osseointegrated dental implants in the rehabilitation of edentulous patients has been extensively documented, with long-term successful outcomes.[1-3] Among available treatment options, overdenture prostheses represent a highly effective and long-term solution, particularly due to their lower cost and the fact that they do not require advanced surgical techniques.[4,5] The success of implant-supported restorations is largely attributed to strict adherence to surgical and prosthetic protocols.[3,6]

In overdenture prostheses, various types of abutments can be used to ensure retention of the prosthesis to the implants. These attachment systems are critical components that directly influence the stability, retention, and overall comfort of the prosthesis. Among the most commonly used abutment types are Locator, ball attachments, OT Equator, Stern ERA, and bar systems.[7-10] Among these, ball attachments are among the most frequently preferred due to their simple design and ease of application, and they are widely used in clinical practice—particularly in two-implant-supported complete dentures, where they have demonstrated successful outcomes.[10]

One of the critical stages in overdenture prosthesis procedures is the secure attachment of the prosthesis to the implants. The housing component used in this process plays a vital role in ensuring both the functional success and long-term durability of the prosthesis. Clinicians must decide whether to incorporate this component into the prosthesis in the laboratory on a gypsum model, or directly chairside in the patient's mouth.[9,11] The laboratory method allows for more precise fit and a controlled workflow, whereas the chairside method facilitates a one-to-one fit in the clinical environment.[12] However, chairside application requires greater clinical skill and typically takes more time. While the laboratory approach is more time-efficient, it may lead to minor discrepancies in intraoral fit.[9,12,13] A fundamental reason for this is that in the chairside method, the components are placed and secured directly onto the implants, while in the laboratory method, the procedure is performed on a gypsum model using implant analogs. Dimensional or positional differences between the implant and the analog may lead to adaptation issues in the laboratory method. In conclusion, both techniques have their own specific advantages and limitations.

As important as the method by which attachments are integrated into the overdenture is the tool used to secure these components onto the implants, as it directly affects clinical outcomes. In routine clinical practice, prosthetic components are often torqued multiple times during the adjustment of provisional restorations and impression-taking procedures, before the final prosthesis is completed. The appropriate tightening of screws with the correct torque is under the clinician's control, emphasizing the necessity of using a calibrated torque wrench. However, some clinicians prefer to use a handheld driver instead of a torque wrench, which results in a wide range of applied torque values that lack standardization. Moreover, when the abutment is tightened, the threads of the screw and the internal threads of the implant may become deformed.[3,14,15]

In overdenture prostheses, the fixation of attachment components can be carried out either in a clinical (chairside) setting or under laboratory conditions. In the chairside technique, the attachments are directly connected to the implants, whereas in the laboratory method, they are connected to implant analogs. The tools used for fixation also differ; the process can be performed using either a hand driver or a calibrated torque wrench. Since the fixation method and the type of tool used can affect the mechanical load on the attachment components and the stability of the connection, these variables are considered to have a significant impact on prosthesis adaptation and long-term success. The aim of this study was to compare the interface fit of ball attachment connections in overdenture systems, performed at both implant and analog levels, using a hand driver or torque wrench, through micro-CT analysis. The findings are expected to contribute to the clinical decision-making process regarding the appropriate connection method during the finalization of overdenture prostheses, either in chairside or laboratory-fabricated workflows. The null hypothesis of this study was that, in overdenture prosthesis systems using ball attachments: (i) there is no statistically significant difference in interface fit between implant and analog connections, (ii) there is no statistically significant difference between connections established with a hand driver and those with a torque wrench, and (iii) there is no statistically significant difference between different implant systems in terms of connection interface adaptation.

Materials and Methods

Sample Preparation

This in-vitro study included a total of 20 dental implants and 20 implant analogs from two different commercial implant systems: BioInfinity (Turkey) and Dentis Co. (Daegu, Korea). Each group contained 10 implants and 10 analogs, and a total of 40 ball attachment abutments (20 implant-level and 20 analog-level) were evaluated. A single operator with 15 years of clinical experience in implant-supported prostheses carried out the procedures in a controlled laboratory setting.

All implant bodies and their corresponding analogs were rigidly secured to a custom-designed metallic platform to simulate clinical stability. For each implant system (BioInfinity and Dentis), ball attachments were initially tightened manually using a handheld driver. Subsequently, the same components were tightened using a calibrated torque wrench, applying the manufacturer-recommended torque values (BioInfinity: 25 Ncm; Dentis: 30 Ncm). To simulate clinical conditions, a 10-minute interval was maintained between the initial manual tightening and the final torque application. This interval was adopted to minimize preload loss due to the settling effect, which typically occurs within the first few minutes to hours after screw tightening. The settling effect refers to the microscopic adjustment of contacting surfaces, resulting in a reduction in clamping force.[16] Siamos et al.[17] recommended retightening the abutment screw 10 minutes after initial loading to compensate for this effect and enhance the stability of the implant–abutment connection.

Scanning and Image Acquisition

Each sample (implant or analog with ball attachment) was scanned under two different conditions: tightened with a hand driver and tightened with a torque wrench. All scans were performed using a high-resolution micro-CT system (SkyScan 1275, Bruker microCT, Kontich, Belgium). A standardized scanning protocol was followed for all samples.

After scanning, image reconstruction was performed using the NRecon software (Version 1.6.9.4, Bruker microCT), incorporating beam hardening correction, ring artifact reduction, and smoothing adjustments to enhance image clarity. Reconstructed datasets were then imported into DataViewer software (Version 1.5.6.2, Bruker microCT) for 3D visualization and sagittal re-slicing of each sample.

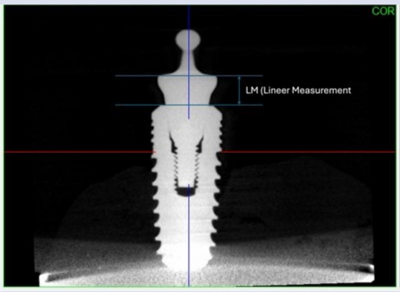

Figure 1. Sagittal micro-CT image showing the vertical linear measurement (LM) from the top shoulder of the ball attachment to the implant platform in the BioInfinity system. LM values indicate the vertical misfit between components when tightened using either a hand driver or a torque wrench.

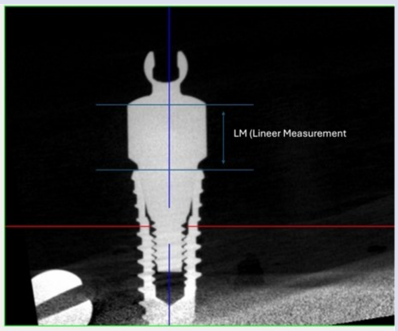

Figure 2. Sagittal micro-CT image showing the vertical linear measurement (LM) from the top shoulder of the ball attachment to the implant platform in the Dentis system. LM values indicate the vertical misfit between components when tightened using either a hand driver or a torque wrench.

Measurements

Linear measurements (in millimeters) were performed by drawing a vertical line from the top surface of the ball attachment to the platform of the implant or analog in the sagittal view (Figure 1 and 2). A total of four measurements were recorded for each sample. Each measurement was performed three times, and the average of these three repetitions was calculated to improve measurement reliability.

- Implant – tightened with a torque wrench
- Implant – tightened with a hand driver
- Analog – tightened with a torque wrench
- Analog – tightened with a hand driver

Higher values indicate a greater vertical discrepancy between the abutment and the platform, reflecting poorer adaptation. Linear measurement was selected as the primary parameter because, even within the same implant system, the internal volumes of implant bodies and analogs are not directly comparable. Thus, linear evaluation provides a more reliable and standardized approach to assess vertical fit and component adaptation.

Statistical Analysis

All statistical analyses were performed using IBM SPSS Statistics software (v26.0; IBM Corp., Armonk, NY, USA). The data obtained were analyzed separately for each system (Dentis and Bioinfinity). In the first stage, the normality of the distribution for the four measurement groups (implant–torque, implant–hand driver, analog–torque, analog–hand driver) was assessed using the Shapiro–Wilk test. For datasets meeting parametric test assumptions, one-way analysis of variance (ANOVA) was performed, followed by Tukey's HSD post-hoc test for multiple comparisons. These analyses were used to evaluate the effects of connection type and tightening method on vertical misfit within each system. To enable inter-system comparison, the absolute differences between torque and hand driver measurements were calculated for each sample, generating two new variables: implant difference and analog difference. These difference values were compared between the two systems (Dentis vs. Bioinfinity) using the independent samples t-test (Student's t-test). A significance level of $p < 0.05$ was considered statistically significant.

Table 1. Statistical analysis of Bioinfinity

Groups	Mean (mm)	SD (mm)	Min (mm)	Max (mm)
Analog_Hand Driver	2.38[a]	0.045	2.34	2.48
Analog_Torque wrench	2.42[b]	0.049	2.38	2.52
Implant_Hand driver	2.13[c]	0.050	2.08	2.20
Implant_Torque wrench	2.20[d]	0.020	2.16	2.24

Superscript letters (a, b, c, d) indicate statistically significant differences between groups based on Tukey's HSD test ($p < 0.05$). Groups that do not share the same superscript letter are significantly different.
SD: Standard deviation; Min: Minimum; Max: Maximum; mm:millimeter

Results

In this study, linear measurements (in mm) were used to evaluate the connection adaptation of ball attachments from two different implant systems (BioInfinity and Dentis), following either manual tightening using a hand driver or mechanical tightening with a torque wrench, in both implant and analog models. The linear measurements were evaluated in millimeters (mm), and lower values were considered indicative of better connection adaptation.

Results for BioInfinity

The linear measurements obtained from the BioInfinity system revealed statistically significant differences among the four experimental conditions: implant–torque wrench, implant–hand driver, analog–torque wrench, and analog–hand driver (One-way ANOVA, $F = 86.19$, $p < 0.001$) (Table 1).

In the implant–ball attachment group, the hand-tightening method resulted in significantly lower linear measurement values compared to the torque wrench ($p < 0.05$). Similarly, in the analog–ball attachment group, hand driver produced significantly lower values than torque wrench ($p < 0.05$).

Overall, implant–ball attachment groups showed significantly lower values compared to analog–ball attachment groups ($p < 0.001$). This suggests that, especially in restorations requiring precise adaptation, the connection between implant and ball attachment provides better compatibility than the analog–ball attachment connection.

Additionally, the use of either a hand driver or a torque wrench in tightening ball attachments to both implants and analogs resulted in statistically significant differences, indicating that the method of screw tightening can influence the connection adaptation.

All these findings demonstrate that both the connection interface (implant vs. analog) and the tightening method have significant effects, and should be considered important factors for clinical success.

Results for Dentis

The linear measurements obtained from the Dentis system showed no statistically significant difference between implant and analog groups ($p > 0.05$); however, a statistically significant difference was observed between the hand driver and the torque wrench methods (paired t-test, $p < 0.05$) (Table 2). These findings indicate that when the ball attachment is connected to either the implant or the analog, comparable linear measurements are achieved; however, the tightening method has a measurable impact on the results. This suggests that the connection stability of the system may be sensitive to the tightening method and highlights the importance of standardization in clinical applications.

Table 2. Statistical analysis of Dentis

Groups	Mean (mm)	SD (mm)	Min (mm)	Max (mm)
Implant_Torque wrench	3.77 a	0.047	3.71	3.85
Implant_Hand driver	3.81 b	0.038	3.78	3.89
Analog_Torque wrench	3.87 a	0.211	3.64	4.30
Analog_Hand Driver	3.94 b	0.234	3.76	4.43

Superscript letters (a and b) indicate statistically significant differences between groups based on Tukey's HSD test ($p < 0.05$). Groups that do not share the same superscript letter are significantly different.
SD: Standard deviation; Min: Minimum; Max: Maximum; mm:millimeter

Table 3. Comparison of implant–analog connection discrepancies between BioInfinity and Dentis systems according to tightening method (torque wrench and hand driver)

Tightening methods	Bioinfinity (Mean ± SD)	Dentis (Mean ± SD)	p-value
Torque Wrench	-0.22 ± 0.06	-0.10 ± 0.22	p = 0.129
Hand Driver	-0.25 ± 0.08	-0.13 ± 0.26	p = 0.198

SD: Standard deviation.

Comparative Results BioInfinity and Dentis

In the implant–ball attachment and analog–ball attachment groups of the BioInfinity and Dentis systems, inter-system comparisons were performed by calculating the difference between torque wrench and hand driver applications. For each sample, the difference between "torque" and "manual tightening" was calculated, and these values were analyzed using an independent samples Student's t-test to compare the two systems. (Table 3; $p > 0.05$).

For the torque wrench method, the mean difference was –0.22 mm in the BioInfinity system and –0.10 mm in the Dentis system, which was not statistically significant Similarly, for the hand driver method, the mean difference was –0.25 mm in the BioInfinity system and –0.13 mm in the Dentis system, and this difference was also not statistically significant ($p > 0.05$). These findings suggest that the differences associated with torque wrench and hand driver applications are comparable across the two systems and do not represent a clinically significant distinction.

Discussion

In this study, the connection interface adaptation of ball attachments to implants and analogs was compared using hand driver and torque wrench methods, and the evaluations were performed using micro-CT. According to the results, Dentis, no statistically significant difference was found between implant and analog connections ($p > 0.05$), whereas a significant difference was observed between the hand driver and torque wrench methods ($p < 0.05$). In contrast, BioInfinity, significant differences were found both between connection types (implant vs. analog) and between tightening methods (hand driver vs. torque wrench) ($p < 0.05$). Moreover, although the difference between hand driver and torque wrench methods was not statistically significant between systems, a system-related difference was observed between implant and analog connections. These findings suggest that sensitivity to the tightening method may vary depending on the connection tolerances and component designs of different implant systems. The null hypothesis of the study was that there would be no significant difference in connection type or tightening method across all systems; however, based on the findings of this study, the null hypothesis was partially rejected.

The findings of the study revealed statistically significant differences in ball attachment connection adaptation between implant bodies and analogs in BioInfinity. The linear measurements obtained at the implant level were found to be significantly lower compared to those at the analog level ($p < 0.001$). This indicates the possibility of micro-misfits at the connection interface, potentially due to the inability of analogs to fully replicate clinical implants. Previous studies have reported that manufacturing tolerances and positioning of analogs on stone casts may lead to deviations from the clinical implant position, potentially affecting prosthetic adaptation.[9,12,13,18,19] These factors may contribute to the differences observed between laboratory-fabricated and clinically seated prostheses.

On the other hand, for Dentis, no statistically significant difference was observed in the ball attachment connection between implants and analogs ($p > 0.05$). This result indicates that the system exhibits high manufacturing precision and that the analogs can successfully replicate the implant body in terms of dimensional and geometric accuracy. Consequently, it can be inferred that prosthetic procedures performed in the laboratory can be reliably transferred to clinical applications. The findings from both groups suggest that different implant systems may yield different outcomes.

The use of analogs during the laboratory fabrication of attachment-retained overdentures may introduce dimensional variability, which could affect the fit of the final prosthesis.[9,20] Therefore, the limitations of analog-based procedures should be considered when high precision is required. In the present study, significantly higher linear discrepancy values were observed in analog connections compared to implant connections, particularly in the BioInfinity system. These results highlight the potential clinical impact of analog-related dimensional differences on prosthetic adaptation and underscore the importance of component selection and standardization in attachment-retained prostheses. In clinical conditions, positive linear discrepancies may indicate microgaps at the connection interface, potentially compromising prosthetic stability or retention. On the other hand, negative values could suggest excessive tightening or misfit, which may lead to mechanical stress or component deformation. Therefore, minimizing these discrepancies is important for achieving long-term success in attachment-retained prostheses

As in all areas of implant dentistry, the proper torque application of abutment screws during the attachment of ball attachments to implants or analogs is of critical importance. Complications such as deformation of the screw threads or the internal structures of the implant or analog can occur during the tightening phase. The control of the applied torque lies with the clinician, which highlights the necessity of using a calibrated torque wrench.[3,14,21,22] However, some clinicians use a hand driver instead of a torque wrench, in which case the applied torque value becomes undefined.[3,15] In this study, the connection adaptation of ball attachments to implants and analogs was analyzed using both hand drivers and torque wrenches.

According to the findings, statistically significant differences were observed between the two tightening methods in both groups. In BioInfinity, the mean linear measurement in the implant–ball attachment group was 2.13 ± 0.05 mm when tightened with a hand driver, compared to 2.20 ± 0.03 mm with a torque wrench. In the analog–ball attachment group, the mean value was 2.38 ± 0.04 mm for the hand driver and 2.44 ± 0.05 mm for the torque wrench. These results indicate that ball attachments were seated deeper when hand drivers were used. In Dentis, the mean value for the implant–ball attachment group was 3.81 ± 0.038 mm with a hand driver and 3.77 ± 0.047 mm with a torque wrench. In the analog–ball attachment group, the values were 3.94 ± 0.234 mm and 3.87 ± 0.211 mm, respectively. In contrast to BioInfinity, ball attachments seated deeper with the torque wrench in the Dentis system. These findings are consistent with previous studies that suggest the use of hand drivers results in undefined and potentially variable torque values.[14,22]

It is critically important not only to apply a minimum required torque but also to avoid overtightening, as excessive torque may exceed the yield strength of the screw, leading to permanent deformation, loss of mechanical properties, and even screw fracture.[3,14,22] This study did not measure torque values directly. However, in the BioInfinity group, linear measurements suggest that the hand driver may have applied more force than recommended. These findings are consistent with the study by Singh et al.,[23] which reported that torque values applied with a hand driver were higher than those applied with a torque wrench. In contrast, for Dentis, it was presumed that the force applied with the hand driver was lower than that of the torque wrench, indicating an opposite trend compared to BioInfinity. This study does not allow for direct measurement of the applied torque or assessment of any resulting screw deformation, as final torque values and screw integrity were not within the scope of the investigation and represent one of the study's limitations. Furthermore, although the hand driver was applied by a single operator in this study, previous research has shown that even a single operator may not produce consistent torque values across different attempts.[24] This factor should be considered when interpreting inter-system differences.

The results of this study indicate that the method of tightening ball attachments—either with a hand driver or a torque wrench—can influence the connection fit in both implant and analog models. These findings highlight the potential for variability in prosthetic fit depending on the clinical or laboratory procedures used and underscore the importance of standardizing tightening protocols during prosthesis fabrication.

This study evaluated the connection interfaces of implants, analogs, and ball attachments tightened with either a hand driver or a torque wrench using micro-CT, in line with previous research.[25-27] Micro-CT is a highly efficient and widely used technique for examining implant components. It enables the acquisition of high-resolution images without causing structural damage or distortion. This method, which allows for precise linear measurements, is considered reliable.[28] In the present study, the use of micro-CT enabled the objective evaluation of potential adaptation discrepancies between implant and analog connections following the use of hand drivers and torque wrenches. High-resolution cross-sectional images enabled a detailed analysis of connection gaps, revealing how the tightening method affected the fit.

This study has several limitations. First, as the research was conductedunder in vitro conditions, biological factors that may be encountered in the oral environment were not considered. Only two implant systems (Dentis and BioInfinity) and a single type of ball attachment were evaluated, excluding other implant systems and attachment types. Additionally, connection adaptation was assessed solely through linear measurements; no further biomechanical analyses such as, volumetric evaluation, stress distribution, or torque value measurements were performed. Moreover, relying exclusively on linear micro-CT measurements may not fully capture three-dimensional or volumetric aspects of the misfit, which represents an inherent limitation of the present evaluation method. Although all manual torque applications were performed by a single experienced operator to ensure consistency, previous studies have shown that even within a single operator, torque values may vary across trials, which could influence the outcome. Despite these limitations, the study provides a valuable contribution to the literature by offering a comparative analysis of implant and analog connections using hand driver and torque wrench methods through advanced imaging techniques such as micro-CT.

Conclusions

This in-vitro study evaluated the influence of two different tightening methods—hand driver and torque wrench—on the connection fit between ball attachments and implants or analogs in two different implant systems. In the BioInfinity system, statistically significant differences were observed between implant and analog connections, while no such difference was found in the Dentis system. In both systems, the tightening method significantly affected the linear fit of the ball attachment connections. These results suggest that the type of connection and the tightening method can influence the adaptation quality of prosthetic components. However, these findings are based on in vitro data obtained from a limited number of implant systems, and further comprehensive studies involving various implant systems and clinical conditions are needed.

Acknowledgement

The authors would like to thank BioInfinity Implant Co. (Turkey) and Dentis Implant Co. (Korea) for kindly providing the implant components used in this study.

Conflicts of Interest Statement

No conflict of interest

References

1. Zarb GA, Schmitt A. The longitudinal clinical effectiveness of osseointegrated dental implants: the Toronto study. Part II: the prosthetic results. J Prosthet Dent 1990;64:53-61.
2. Adell R, Eriksson B, Lekholm U, Branemark PI, Jemt T. A long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. Int J Oral Maxillofac Implants 1990;5:347-359.
3. Kanawati A, Richards MW, Becker JJ, Monaco NE. Measurement of clinicians' ability to hand torque dental implant components. J Oral Implantol 2009;35:185-188.
4. Naert I, Alsaadi G, Quirynen M. Prosthetic aspects and patient satisfaction with two implant-retained mandibular overdentures: a 10-year randomized clinical study. Int J Prosthodont 2004;17:40110.
5. Scherer MD. Overdenture implants. A simplified and contemporary approach to planning and placement. Dent Today 2015;34:54,56-8,60.
6. Hemmings KW, Schmitt A, Zarb GA. Complications and maintenance requirements for fixed prostheses and overdentures in the edentulous mandible: a 5-year report. Int J Oral Maxillofac Implants 1994;9:191-196.
7. Phillips K, Wong KM. Space requirements for implant-retained bar-and-clip overdentures. Compend Contin Educ Dent 2001;22:516-8,520,522.
8. Lee CK, Agar JR. Surgical and prosthetic planning for a two-implant-retained mandibular overdenture: a clinical report. J Prosthet Dent 2006;95:102-105.
9. Scherer MD. When to use laboratory vs. chairside processing of overdentures. Inside Dent Technol 2021;12:16-23.
10. Ortensi L, Martinolli M, Borromeo C, Ceruso FM, Gargari M, Xhanari E, Tallarico M. Effectiveness of ball attachment systems in implant retained- and supported-overdentures: a three- to five-year retrospective examination. Dent J 2019;7:84.
11. Lambade D, Lambade P, Gundawar S. Implant supported mandibular overdenture: a viable treatment option for edentulous mandible. J Clin Diagn Res 2014;8:ZD04.

12. Elsewedy M, Nabil M, Habib A. Direct versus indirect pick up of the locator retentive caps for four implant retained mandibular overdenture: (within patient study). IOSR J Dent Med Sci 2023;22:12-15.
13. Boudrias PO, Chehade A. Two-implant overdentures with ball attachments: a step-by-step approach. In: Feine JS, Carlsson GE, eds. Implant overdentures: the standard of care for edentulous patients. Carol Stream, Ill: Quintessence Publishing Co; 2003. p.129-143.
14. Sameera Y, Rai R. Tightening torque of implant abutment using hand drivers against torque wrench and its effect on the internal surface of implant. J Indian Prosthodont Soc 2020;20:180-185.
15. Hill EE, Phillips SM, Breeding LC. Implant abutment screw torque generated by general dentists using a hand driver in a limited access space simulating the mouth. J Oral Implantol 2007;33:277-279.
16. Klongbunjit D, Aunmeungtong W, Khongkhunthian P. Implant-abutment screw removal torque values between customized titanium abutment, straight titanium abutment, and hybrid zirconia abutment after a million cyclic loading: an in vitro comparative study. Int J Implant Dent 2021;7(1):98.
17. Siamos G, Winkler S, Boberick KG. The relationship between implant preload and screw loosening on implant-supported prostheses. J Oral Implantol 2002;28(2):67-73.
18. Katsoulis J, Takeichi T, Sol Gaviria A, Peter L, Katsoulis K. Misfit of implant prostheses and its impact on clinical outcomes: definition, assessment and a systematic review of the literature. Eur J Oral Implantol 2017;10(Suppl 1):121-138.
19. Vigolo P, Majzoub Z, Cordioli G. In vitro comparison of master cast accuracy for single-tooth implant replacement. J Prosthet Dent 2000;83:562-566.
20. Dominici JT, Kinderknecht KE, Patella-Clark E. Clinical procedure for stabilizing and connecting O-ring attachments to a mandibular implant overdenture. J Prosthet Dent 1996;76:330-333.
21. Worthington P, Lang BR, Rubenstein JE. Osseointegration in dentistry: an overview. 2nd ed. Chicago, Ill: Quintessence; 2003.
22. Vidal IBM, Lages FS. Dental torque wrench: relevance in implant dentistry and influence of use. Rev Estomatol 2024;32:1.
23. Singh H, Sonkesriya S, Patel BJ, Rathod V, Gupta B, Vyas T, Makkad RS. Implant abutment using hand drivers versus torque wrench. Bioinformation 2023;19:19(2):221-225.
24. Jaarda MJ, Razzoog ME, Gratton DG. Providing optimum torque to implant prostheses: a pilot study. Implant Dent 1993;2:50-52.
25. Kose OD, Karataslı B, Demircan S, Kose TE, Cene E, Aydın Aya S, Erdem MA, Cankaya AB. In vitro evaluation of manual torque values applied to implant-abutment complex by different clinicians and abutment screw loosening. Biomed Res Int 2017;2017:7376261.
26. Schicho K, Kastner J, Klingesberger R, Seemann R, Enislidis G, Undt G, Figl M, Wagner A, Ewers R. Surface area analysis of dental implants using micro-computed tomography. Clin Oral Implants Res 2007;18:459-464.
27. Erpaçal B, Adıgüzel Ö, Cangül S. The use of micro-computed tomography in dental applications. Int Dent Res 2019;9:78-91.
28. Min CK, Kim KAA. Quantitative analysis of metal artefacts of dental implant in CBCT image by correlation analysis to micro-CT: a microstructural study. Dentomaxillofac Radiol 2021;50:20200365.