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Different Palatal Coverage designs as a Determinant of Stress Distribution on Locator attachment Maxillary implant Overdenture

Bahauldin Ieisay Amhamad [1*], Fatimah Khalifa Ahmed [2], Hosam E. Elarabi [3]
[1,2] Department of Prosthodontics, Faculty of Dentistry, Gharyan University, Libya
[3] Department of Conservative, Faculty of dentistry, Garyan university, Libya
*Corresponding author: baha.miftah@gu.edu.ly

تصاميم تغطية الحنك المختلفة كعامل محدد لتوزيع الإجهاد على طقم الأسنان العلوي المدعوم بزرعات الأسنان باستخدام وصلات لوكيتور

بهاء الدين عيسى إمحمد [1*]، فاطمة خليفة أحمد [2]، حسام العجيلي العربي [3]
[1،2] قسم الاستعاضة في طب الأسنان، كلية طب الأسنان، جامعة غريان، ليبيا
[3] قسم العلاج التحفظي، كلية طب الأسنان، جامعة غريان، ليبيا

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Abstract
This in vitro study aimed to evaluate the strain distribution around two and four implants supporting maxillary implant overdentures retained by Locator attachments with different palatal coverage designs (full versus partial). Four identical acrylic models simulating completely edentulous maxillary arches were fabricated and covered with a polyvinyl siloxane layer to mimic the oral mucosa over the residual ridge. The models were divided into two main groups according to the number of implants (two or four), and each group was further subdivided based on palatal design (full or partial palatal coverage).
Locator abutments were connected to the implants using the manufacturer's driver, and the overdenture frameworks were subsequently constructed. Four strain gauges were bonded to each implant fixture using strain gauge adhesive to record peri-implant microstrain values. A digital loading device (LLOYD Instruments) was used to apply controlled compressive loads, and the resulting strain values around the implants were measured for each configuration.
Statistical analysis revealed a significant difference between two-implant overdentures with full palatal coverage (30.64 ± 17.47 µε) and those with partial palatal coverage (49.72 ± 23.17 µε), with higher strain values observed in the partial coverage design. In contrast, although four-implant overdentures with partial palatal coverage (8.77 ± 4.54 µε) demonstrated higher mean strain values than those with full palatal coverage (5.51 ± 3.83 µε), the difference was not statistically significant.
Within the limitations of this in vitro study, full palatal coverage reduced peri-implant strain compared with partial palatal coverage in two-implant-supported maxillary overdentures. For four-implant-supported overdentures, full palatal coverage also showed lower strain values; however, the difference was not statistically significant.

Keywords: Maxillary implant overdenture; Palatal coverage; Locator attachment; Strain gauge analysis; Implant biomechanics.

الملخص
هدفت هذه الدراسة المعملية (in vitro) إلى تقييم توزيع الانفعال حول زرعتين وأربع زرعات تدعم أطقم الأسنان العلوية المدعومة بالزرعات والمثبتة بوصلات لوكيتور، وذلك بمقارنة تصاميم تغطية الحنك الكاملة والجزئية. تم تصنيع أربعة نماذج أكريليك متطابقة تمثل أقواس الفك العلوي عديمة الأسنان تمامًا، وغُطيت بطبقة من مادة البولي فينيل سيلوكسان لمحاكاة الغشاء المخاطي المغطي للحافة السنخية المتبقية. قُسمت النماذج إلى مجموعتين رئيسيتين وفقًا لعدد الزرعات (زرعتان أو أربع زرعات)، ثم قُسمت كل مجموعة إلى مجموعتين فرعيتين حسب تصميم تغطية الحنك (كاملة أو جزئية).
تم تثبيت دعامات اللوكاتور على الزرعات باستخدام الأداة المخصصة من الشركة المصنعة، ثم تم تصنيع هياكل الأطقم وفق التصميمات المحددة. ثُبتت أربعة مقاييس انفعال على كل زرعة باستخدام مادة لاصقة خاصة بمقاييس الانفعال لتسجيل قيم الانفعال حول الزرعات. استُخدم جهاز تحميل رقمي لتطبيق أحمال ضغط محكومة، وتم تسجيل قيم الانفعال الناتجة لكل تصميم.
أظهر التحليل الإحصائي وجود فرق معنوي بين الأطقم المدعومة بزرعتين مع تغطية حنكية كاملة (30.64 ± 17.47 ميكروانفعال) وتلك ذات التغطية الجزئية (49.72 ± 23.17 ميكروانفعال)، حيث سُجلت قيم أعلى في تصميم التغطية الجزئية. أما في حالة الأطقم المدعومة بأربع زرعات، فقد أظهرت التغطية الجزئية (8.77 ± 4.54 ميكروانفعال) متوسط قيم أعلى مقارنة بالتغطية الكاملة (5.51 ± 3.83 ميكروانفعال)، إلا أن هذا الفرق لم يكن ذا دلالة إحصائية.

ضـمن حدود هذه الدراسـة المعملية، أدى تصـميم التغطية الحنكية الكاملة إلى تقليل الانفعال حول الزرعات مقارنة بالتغطية الجزئية في حالة الأطقم المدعومة بزرعتين، كما أظهر قيماً أقل في حالة الأربع زرعات، إلا أن الفروق لم تصـــل إلى مستوى الدلالة الإحصائية.

الكلمات المفتاحية: الطقم العلوي المدعوم بالزرعات؛ تغطية الحنك؛ وصـــلة اللوكاتور؛ تحليل الانفعال؛ ميكانيكا الزرعات السنية.

Introduction:

Removable complete dentures remain a conventional and cost-effective treatment option for the rehabilitation of edentulous patients. However, many patients experience problems related to denture instability, discomfort, and reduced masticatory efficiency, which often compromise overall satisfaction and quality of life, leading clinicians to consider implant-supported prosthetic solutions (1).

Implant-supported overdentures (IODs) provide significant advantages compared with conventional dentures, including improved retention and stability, enhanced masticatory performance, and greater patient comfort, ultimately resulting in higher levels of patient satisfaction and oral health-related quality of life (2,3).

The maxilla presents unique biomechanical challenges compared with the mandible. Bone resorption patterns in the maxilla often result in implants being positioned with increased labial inclination and at greater distances from the center of the prosthesis, which may increase leverage forces and torque transmitted to implants and attachment components during function (4). Consequently, the design of the overdenture, particularly the extent of palatal coverage, plays an important role in load distribution.

Palatal coverage may be indicated in certain clinical situations, especially when implant support is limited, to enhance tissue support and reduce load transfer to the implants (5). Conversely, palateless overdentures are sometimes preferred to improve patient comfort, phonetics, and taste perception, and previous studies have reported comparable functional outcomes between palateless and conventional palatal coverage dentures under specific conditions (6).

When selecting attachment systems for implant overdentures, several factors must be considered, including cost effectiveness, required retention, hygiene maintenance, available bone support, interarch relationship, patient expectations, and implant distribution (7,8). Among the available attachment systems, the Locator attachment has gained widespread popularity due to its low profile, dual retention mechanism, ease of maintenance, and favorable wear characteristics (9).

Therefore, the aim of this in vitro study was to evaluate the strain distribution around two and four implants supporting Locator-retained maxillary implant overdentures with different palatal coverage designs (full versus partial).

Materials and Methods:

Four identical acrylic models representing completely edentulous maxillary arches were fabricated for this experimental study. According to El Charkawi et al. (10), the residual ridge areas were covered with a 1.7-mm layer of polyvinyl siloxane impression material to simulate the oral mucosa and its viscoelastic behavior.

The models were divided into two main groups according to the number of implants:

Group I: Two implants placed bilaterally in the canine regions.
Subgroup IA: Full palatal coverage design.
Subgroup IB: Partial palatal coverage design.
Group II: Four implants placed bilaterally in the canine and second premolar regions.
Subgroup IIA: Full palatal coverage design.
Subgroup IIB: Partial palatal coverage design.

In Group I, two implants were installed vertically in the canine regions with an inter-implant distance approximating that of natural canines. In Group II, four implants were placed in the canine and second premolar regions using a surgical guide to ensure standardization.

Locator abutments were connected to the implants using the manufacturer's driver, with the cuff height adjusted to extend approximately 1 mm above the simulated mucosal layer. The corresponding metal housings were incorporated into the overdenture frameworks.

Metal frameworks were constructed so that the meshwork minor connectors were positioned over the ridge crest area. In the full palatal coverage design, the metal base extended to cover the entire palate, whereas in the partial palatal coverage design, a defined finishing line was placed along the anterior and lateral palatal slopes.

Measurement of the Strain transmitted to the implants:

A channel corresponding to each implant fixture was prepared in the model base to allow passage of strain gauge wires, and grooves were created to secure the wiring.

Four strain gauges were bonded to the cervical third of the mesial, distal, buccal, and palatal surfaces of each implant fixture using strain gauge adhesive. The gauges were connected to a data acquisition system to record microstrain values.

Bilateral loading was applied using a standardized stainless-steel bar (6 cm length and 5 mm diameter), with the midpoint aligned with the loading point. A digital universal testing machine (LLOYD Instruments) was used to apply a static compressive load of 50 N. Multiple readings were recorded for each configuration to improve measurement reliability.

Statistical analysis:

Data normality was assessed using the Shapiro–Wilk test. Descriptive statistics were calculated, including minimum, maximum, mean, median, and standard deviation values of peri-implant microstrain.

Two-way analysis of variance (ANOVA) was used to evaluate the effects of palatal design and implant number on recorded strain values, followed by appropriate post hoc comparisons when indicated. The level of statistical significance was set at **$P \leq 0.05$**. Statistical analysis was performed using SPSS software (Statistical Package for the Social Sciences).

Results:

Table 1 shows the comparison of peri-implant microstrain values in models with two implants placed in the canine regions and retained by Locator attachments using full palatal coverage (Group I-A) and partial palatal coverage (Group I-B) designs.

A statistically significant difference was observed between the two designs. The mean microstrain recorded with full palatal coverage (30.64 ± 17.47 με) was significantly lower than that recorded with partial palatal coverage (49.72 ± 23.17 με), as illustrated in Figure 1.

Table 1. Comparison of peri-implant microstrain values in models with two implants retained by Locator attachments using full and partial palatal coverage designs.

Two implants with Locator attachments							
Full palatal coverage design μ ε				**Partial palatal coverage design μ ε**			
Min	**Max.**	**Mean ± SD.**	**Median**	**Min.**	**Max.**	**Mean ± SD.**	**Median**
6.3	55.3	**30.64 ± 17.47**	26.3	17.2	86.1	**49.72 ± 23.17**	40.0

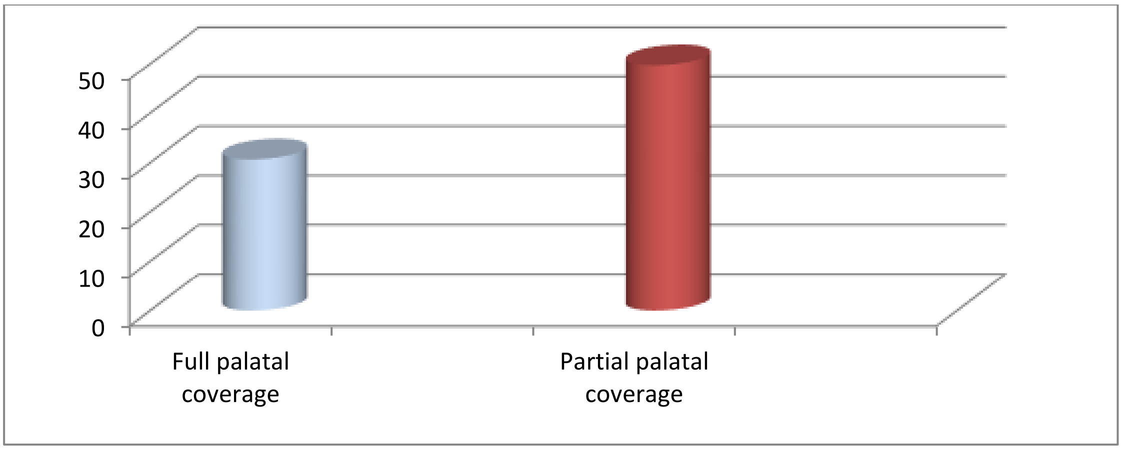

Figure 1. Comparison of peri-implant microstrain values in models with two implants retained by Locator attachments using full and partial palatal coverage designs.

Table 2 shows the comparison of peri-implant microstrain values in models with four implants retained by Locator attachments, with two implants placed in the canine regions and two implants in the second premolar regions, using full palatal coverage (Group II-A) and partial palatal coverage (Group II-B) designs.

There was no statistically significant difference between the two designs. The mean microstrain value recorded with full palatal coverage (5.51 ± 3.83 με) was lower than that recorded with partial palatal coverage (8.77 ± 4.54 με), as illustrated in Figure 2.

Table 2. Comparison of peri-implant microstrain values in models with four implants retained by Locator attachments using full and partial palatal coverage designs.

Four implants with Locator attachments							
Full palatal coverage design μ ε				**Partial palatal coverage design μ ε**			
Min.	**Max.**	**Mean ± SD.**	**Median**	**Min.**	**Max.**	**Mean ± SD.**	**Median**
0.5	14.1	**5.51 ± 3.83**	4.3	2.2	18.7	**8.77 ± 4.54**	8

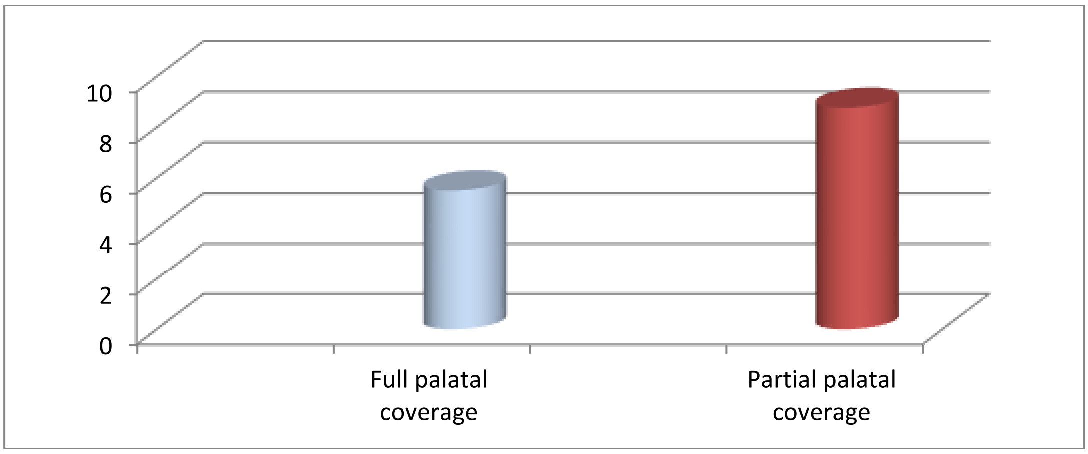

Figure 2. Comparison of peri-implant microstrain values in models with four implants retained by Locator attachments using full and partial palatal coverage designs.

Discussion:

In vitro strain analysis was selected in the present study because it allows precise measurement under controlled and standardized conditions, which are difficult to achieve in clinical situations due to the complex nature of intraoral loading (11).

To simulate the mucosal layer covering the residual ridge, a polyvinyl siloxane material with a thickness of approximately 1.7 mm was used, as previously described in experimental models investigating implant overdentures (12). This approach provides a reasonable approximation of the viscoelastic behavior of oral soft tissues.

Strain gauges were used as the measurement method because they offer direct quantitative evaluation of deformation around implants and have been widely employed in biomechanical dental research due to their simplicity, accuracy, and cost-effectiveness compared with other techniques such as photoelastic analysis and finite element modeling (13).

The findings of the present study demonstrated higher strain values in two-implant configurations compared with four-implant configurations, which is consistent with the biomechanical principle that increasing implant number improves load distribution and reduces stress concentration. Previous clinical and experimental studies have also reported improved biomechanical stability with four implants in maxillary overdentures (14,15).

Full palatal coverage resulted in lower strain values compared with partial palatal coverage, particularly in the two-implant models. This may be attributed to the additional tissue support provided by the palatal base, which contributes to load sharing between the implants and the supporting tissues. Similar observations were reported in studies evaluating overdenture designs with varying palatal support (16,17).

The present results also showed greater strain values around posterior implants compared with anterior implants, which may be explained by the increased lever arm and occlusal loading forces in posterior regions. This finding agrees with previous reports describing higher stress concentration in posterior implant positions (18).

Conclusion:

1. Full palatal coverage design resulted in lower peri-implant strain values compared with partial palatal coverage in two-implant-supported maxillary overdentures retained by Locator attachments.
2. In four-implant-supported overdentures, full palatal coverage also demonstrated lower strain values than partial coverage; however, the difference was not statistically significant.
3. Increasing the number of implants from two to four reduced the magnitude of peri-implant strain under the same loading conditions and attachment system.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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