

# Interchangeability of Contemporary Semi-adjustable Articulators Used Over Time: An *In Vitro* Study

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## ABSTRACT

**Aim:** The purpose of this study is to investigate the interchangeability of newly acquired, short-term used, and long-term used semi-adjustable articulators.

**Materials and methods:** Metal analogs of partially dentate maxillary and mandibular arches were mounted on twelve semi-adjustable Stratos 300 articulators, divided into three groups based on usage over time: New, short-term used (<2 years), long-term used (>2 years) articulators. Each articulator was calibrated according to manufacturer guidelines, ensuring consistency. Occlusal contact forces were recorded using a T-scan III device with a pressure-mapping sensor. Maximum intercuspation (MIP) contact magnitudes were recorded by two calibrated examiners at 10-second intervals, ensuring reliable data collection across all conditions.

**Results:** In MIP, tooth #9 consistently exhibited the highest contact percentages across all articulator conditions, with percentages of 22.2% in the new articulator, 21.8% in the short-term used articulators, and 21.5% in long-term used articulators, indicating stable contact force distribution. Tooth #12 consistently showed the lowest MIP contact percentages, suggesting minimal occlusal force in this region due to its absence. Contact forces, measured at 10-second intervals, showed no significant differences among the different articulator conditions in MIP ( $p > 0.01$ ).

**Conclusion:** Within the limitations of this *in vitro* study, the calibrated Stratos 300 semi-adjustable articulator maintained superior accuracy over time.

**Clinical significance:** The study confirms that the calibrated Stratos 300 semi-adjustable articulators provide consistent and accurate occlusal measurements over time, regardless of their usage over time.

**Keywords:** Articulators, Interchangeability, Semi adjustable articulators.

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## INTRODUCTION

A dental articulator is a mechanical instrument designed to simulate the temporomandibular joints and jaws, facilitating the replication of various mandibular movements within a laboratory setting.<sup>1</sup> The accurate transfer of a patient's mandibular movements to the laboratory is crucial for the precise fabrication of dental prostheses.<sup>2</sup> This process significantly reduces interferences and deflections in the prosthesis, thereby minimizing the need for chair side adjustments and modifications to the occlusal surface. Inaccurate occlusal harmony can lead to periodontal complications and potentially initiate parafunctional habits.<sup>3,4</sup>

Articulators are usually calibrated by manufacturers using special alignment devices to ensure interchangeability, which is essential for reducing positional errors when transferring mounted casts between articulators.<sup>5</sup> This minimizes the need to resend cases to the lab and reduces the likelihood of refabrication of prostheses.<sup>6</sup> Studies have reported varying levels of discrepancy in different articulator models. For example, one study reported a horizontal discrepancy of 32  $\mu\text{m}$  and no vertical discrepancy in Whip-Mix model #2,240 articulators.<sup>7</sup> In contrast, another study found discrepancies up to 250  $\mu\text{m}$  in new Hanau modular articulators, although some studies have deemed them clinically interchangeable.<sup>5,8,9</sup> Additionally, long-term use of articulators can potentially reduce their interchangeability.<sup>10</sup>

Digital articulators offer the potential to overcome the limitations of conventional articulators by accurately reproducing dynamic movements. However, adopting virtual articulators requires investment in a digital scanner system and compatible software for analyzing jaw movements. Additionally, these digital

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technologies need considerable refinement to become practically useful in daily practice. Therefore, analog articulators remain essential in many practices, leading manufacturers to develop interchangeable analog articulator systems.<sup>11</sup> Interchangeable articulator offer several advantages, including fewer articulators being needed to accommodate multiple ongoing treatments, reducing damage to articulators as transportation is minimized; improved ease of communication with the dental laboratory

**Table 1:** Articulators used in the experiment

Articulators	Year in service	Number (N)
Heavily used articulators (HUA)	2 years and more	4
Lightly used articulator (LUA)	Less than 2 years	4
New articulators (NAs)	New	4

technician, and reducing transmission of infectious agents between the dental office and laboratory.

However, semi-adjustable articulators cannot fully replicate mandibular movements due to their straight-line movement and inability to adjust certain condylar parameters, such as intercondylar distance, immediate side shift, and superior and rear wall settings.<sup>12</sup> This limitation can result in inaccurate representation of mandibular movements during eccentric motions.<sup>13,14</sup> The Stratos 300 is a semi-adjustable articulator that accommodates most condylar movements, except for intercondylar distance, offering a practical balance between adjustability and usability in clinical practice.<sup>15</sup>

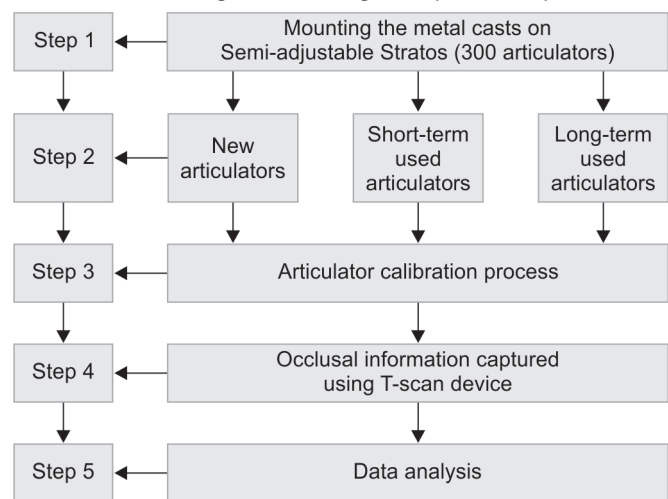
This study aims to investigate the interchangeability of the semi-adjustable Stratos 300 articulator using digital occlusal analysis for both brand-new, short-term used, and long-term used articulators. The null hypothesis is that the interchangeability of new and used articulators remains the same.

## MATERIALS AND METHODS

Metal analogs of maxillary and mandibular partially dentate arches were constructed to serve as standardized models mounted on semi-adjustable Stratos 300 articulators with mounting stone (Whipmix, USA). For our study, twelve semi-adjustable Stratos 300 articulators from Ivoclar were utilized, divided into three groups to reflect varying periods of clinical use. Group I included four new semi adjustable articulators (NA). Group II comprised four short-term used articulators (STA) that had been used for less than 2 years. Group III consisted of four long-term used articulators (LTA) that had been in service for more than 2 years (Table 1). The sample size was determined based on a prior power analysis, considering a pilot study, and allowing for the detection of a mean difference with approximately 80% power while accounting for multiple comparison adjustment.

Before the experimental use, all articulators were subjected to a calibration process as specified by the manufacturer.<sup>16</sup> The process started with the removal of all detachable components, such as the screw-retained mounting plates, incisal pin and holder, incisal table, and lower retaining screw. Subsequently, the calibration pin was inserted into the upper member. To prepare for calibration, stickers were placed over the holes of the lower member, a magnetic base was fastened to the upper member, and the calibration tool was positioned onto the inverted upper screw-retained magnetic base. The lower epoxy-retained magnetic base was then situated atop the calibration tool. Next, a uniform application of 5 mL of calibration liquid was spread over the lower magnetic mounting base. The articulators were then closed to ensure contact between the calibration pin and the lower member and were left to cure undisturbed for approximately 45 minutes. Following this period, calibration verification was conducted for each articulator (Flowchart 1).

Occlusal information was analyzed using a T-scan device (T-scan III, Software version 8.0.1) equipped with a large-size pressure-mapping sensor. The T-scan was mounted on a jig to ensure consistent positioning throughout the experiment (Fig. 1). Measurements of the maximum intercuspation (MIP) contact forces

**Flowchart 1:** Flow diagram illustrating the experimental process

**Fig. 1:** T-scan device positioned in the positional jig and recording the contacts in MIP

for each tooth, without applying external pressure, were recorded at 10-second intervals (Fig. 2). The study commenced in January 2021 and required 6 months to complete the experiment.

The data obtained were analyzed using statistical software (IBM SPSS Statistics, V26.0; IBM Corp). A one-way ANOVA test followed by Bonferroni *Post hoc* tests was performed to determine any significant differences among each group.

## RESULTS

The total contact forces by percentage per tooth are shown in Table 2. In MIP, the highest contact percentages were consistently observed in tooth #9 across all articulator conditions. Specifically, tooth #9 exhibited contact percentages of 22.2% in the new articulators, 21.8% in the short-term used articulators, and 21.5% in the long-term used articulators. This indicates a relatively stable contact force distribution in this tooth, irrespective of the condition of the articulator. Conversely, the lowest MIP contact percentages were recorded in tooth #12 across all articulators, suggesting a consistent pattern of minimal occlusal force in this region due to tooth missing.

All contact forces were measured and recorded at a 10-second interval to ensure consistency in data collection (Fig. 1). Statistically, there were no significant differences in contact forces among the

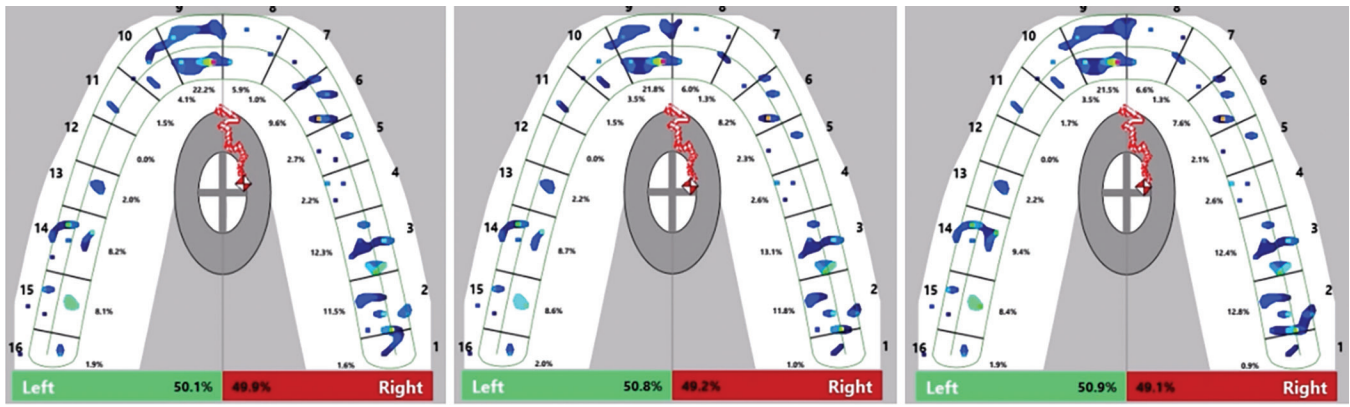


Fig. 2: Occlusal contacts on the T-scan recording screen for MIP at 10 seconds interval

Table 2: Magnitude of the highest occlusal contacts in maximum intercuspal position per tooth. Green color indicates the highest occlusal contacts, while red indicates the lowest occlusal contacts

Locations/ articulators	New	Lightly used (<2 years)	Heavily used (>2 years)
#1	1.6%	1.0%	0.9%
#2	11.5%	11.8%	12.8%
#3	12.3%	13.1%	12.4%
#4	2.2%	2.6%	2.6%
#5	2.7%	2.3%	2.1%
#6	9.6%	8.2%	7.6%
#7	1.0%	1.3%	1.3%
#8	5.9%	6.0%	6.6%
#9	22.2%	21.8%	21.5%
#10	4.1%	3.5%	3.5%
#11	1.5%	1.5%	1.7%
#12	0.0%	0.0%	0.0%
#13	2.0%	2.2%	2.2%
#14	8.2%	8.7%	9.4%
#15	8.1%	8.6%	8.4%
#16	1.9%	2.0%	1.9%

Table 3: Statistical analysis for occlusal contacts in maximum intercuspation

Articulator condition	Test statistic	Std. error	Std. test statistic	p	Adj. p
New-lightly used	-0.44	4.95	-0.09	0.93	1
New-heavily used	-0.03	4.95	-0.01	0.995	1
Lightly-heavily used	0.41	4.95	0.08	0.935	1

different conditions of the articulators in the MIP position ( $p > 0.01$ ), as shown in Table 3. This result suggests that the condition of the articulator whether new, semi-used, or used does not significantly affect the distribution of contact forces in MIP.

Furthermore, the results indicate that the Stratos 300 semi-adjustable articulator maintains a high level of interchangeability and reliability in replicating occlusal contacts. The consistency in the contact force distributions across different articulator conditions suggests that this model is effective in minimizing the need for extensive chairside adjustments and ensuring precise prosthetic fabrication (Table 3).

## DISCUSSION

The interchangeability of the Stratos 300 semi-adjustable articulators under various usage conditions in MIP was thoroughly evaluated in this experiment. The results demonstrated comparable outcomes across different conditions of the articulators, thereby supporting the null hypothesis that the interchangeability of new and long-term used articulators remains consistent. Specifically, the highest contact percentages were remarkably similar across all articulator conditions, with no statistically significant differences observed.

To achieve accurate occlusal contact measurements, various methods have been employed in previous studies. These include the use of shimstock,<sup>17</sup> bite registration materials, and digital scanning techniques.<sup>18,19</sup> However, these traditional methods often fall short in assessing the intensity of occlusal contacts with precision. In contrast, this study utilized the T-scan occlusal analysis system, which measures the contact intensity per tooth, providing a clearer and more accurate representation of occlusal forces.<sup>20</sup> This methodological enhancement offers significant advantages over previous techniques by delivering detailed insights into occlusal contact intensity, which is crucial for effective prosthesis fabrication.

The simulation of bite forces on the articulator was standardized by applying forces with different weights. Various studies have utilized different weights to ensure measurement accuracy, recognizing that the location and application of these weights can significantly influence the contact forces on the articulators.<sup>18,21</sup> In this study, cobalt-chromium casts were employed due to their sufficient weight and inherent strength, eliminating the need for additional external forces. This approach ensured the reliability and consistency of the occlusal force measurements throughout the experiment.

Commonly used materials for fabricating experimental casts, such as stone and printed resins, often lack surface hardness and are prone to abrasion, which can lead to inaccurate data.<sup>22-26</sup> To mitigate this issue, metal casts were used in this study. The metal casts provided adequate strength and hardness, which remained unaffected by repeated experimentation, thereby eliminating the risks associated with cast abrasion and ensuring the accuracy of the data collected.

Despite the rigorous methodology, this study has inherent limitations due to its laboratory setting. The controlled environment of the laboratory does not fully replicate the complexity of the oral environment, where patient-specific factors such as bite force variation, the intricate anatomy of the temporomandibular joint,

and the influence of muscles and ligaments play significant roles. Additionally, while all articulators in this study were strictly calibrated prior to use, this level of calibration may not be consistently achieved in a clinical setting, where articulators may be used without such precise calibration, potentially affecting their performance.

Future research should focus on exploring the impact of using non-calibrated articulators in a clinical environment to validate these findings further. Additionally, studies incorporating a broader range of patient-specific variables, such as varying bite forces and the anatomical complexity of individual patients, would provide a more comprehensive understanding of articulator performance in real-world clinical scenarios.

## CONCLUSION

Within the limitations of this *in vitro* study, the following conclusions can be drawn,

- The Stratos 300 semi-adjustable articulators demonstrated reliability and interchangeability in replicating occlusal contacts. This minimizes the need for extensive chair side adjustments and ensures precise prosthetic fabrication.
- The Stratos 300 appears to maintain superior accuracy in static positions, regardless of the articulator's condition, provided proper calibrations are performed.

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