# Variation in Dental Occlusal Schemes Two Years After Placement of Single-Implant Posterior Crowns: A Preliminary Study

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Some authors have recommended that implant-supported single crowns should only contact during heavy clenching. However, a lack of occlusal contact with moderate clenching may cause supraeruption of antagonist natural teeth. The main objective of this study was to assess changes in the occlusal contacts of posterior implant-supported single crowns with natural antagonist teeth 2 years after placement. The occlusal schemes of 14 patients who received 16 implant-supported single crowns in molar and premolar regions were assessed in this prospective study. Just after crown placement, at 6 months and after 2 years, a silicone maxillomandibular relationship and T-scan records were obtained during the intercuspal position with light and heavy clenching, determined using near half of the maximum force and maximum force, respectively. Occlusal contacts were assessed quantitatively and qualitatively in the implant-supported single crowns, contralateral tooth, and adjacent tooth; the latter 2 were used as controls. After 6 months and 2 years, no significant variations were observed in any region of the occlusal scheme in any assessments, including silicone record or T-Scan, using light or heavy clenching, and qualitative or quantitative occlusal contact assessment. In this preliminary study, the occlusal scheme did not vary at the intercuspal position 2 years after placing posterior implant-supported single crowns.

***Key Words: occlusal scheme, implant-supported single crown, T-Scan, Occlufast***

## INTRODUCTION

Loss of teeth may impair masticatory function, speech, aesthetics, and quality of life.[1] In addition, loss of permanent teeth in the posterior region may cause supraeruption of opposing teeth and tipping or rotation of the adjacent teeth toward the site of loss.[2–4] Treatment options to replace a single missing tooth include a tooth-supported fixed dental prosthesis or an implant-supported single crown (ISC).[5] Although dental implants have demonstrated excellent clinical survival, longitudinal studies suggest an increased incidence of biological and technical complications when compared with tooth-supported fixed dental prostheses.[6,7] Major causes of ISC failures include mechanical (eg, screw loosening or fracture, veneering material fracture, and implant fracture) and biological (peri-implant bone loss) complications. Occlusal overloading might be the primary etiologic factor in biomechanical complications, and in the presence of dental plaque, may lead to bone loss.[8,9]

Several factors should be considered for the occlusion of restorations on natural teeth and implant-supported prostheses, because the presence or not of the periodontal ligament. The axial mobility of the teeth is 25–100 μm, whereas the axial displacement of osseointegrated implants is 3–5 μm.[10,11] Additionally, dental implants exhibit low tactile sensitivity, low proprioceptive motion feedback, and no mesial drifting.[12] Therefore, the occlusal guidelines for implant-supported prostheses recommends axial loading of implants by cusps in the opposing tooth central fossa, reduced cuspal inclination, and wide grooves and fossae.[11,13] Single-tooth implant crowns in the posterior region with a natural dentition in the opposing arch should be free of occlusion on excursive movements, should have light contact for heavy occlusal force, and should have no contact for light occlusal force at the intercuspal position.[7,9,13] However, there is no evidence that this occlusal scheme is valid, because few clinical studies in the field of implant occlusion are available.[9,12]

To achieve prosthetic durability and to maintain masticatory function, the occlusion scheme should not vary significantly over time.[14,15] It is known that teeth continue to erupt until they find a stable occlusion. When antagonistic contact is lost, we can expect the tooth to migrate vertically, leading to

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Table 1

Description of implant locations, sizes and connection types*

| | Implant Position | | | Implant Characteristics | | | | |
|---|---|---|---|---|---|---|---|---|
| | Jaw | Side | Region | Length | Diameter | Connection | Brand | Exclusion |
| 1 | Mand. | Left | Premolar | 11 | 3.5 | Internal hexagon | † | |
| 2 | Mand. | Right | Molar | 10 | 4.8 | External hexagon | ‡ | |
| 3 | Mand. | Left | Premolar | 7 | 3.8 | Internal hexagon | ‡ | |
| 4 | Mand. | Left | Premolar | 13 | 3.8 | External hexagon | § | |
| 5 | Mand. | Right | Molar | 12 | 5.8 | Internal hexagon | \| | |
| 6 | Mand. | Right | Molar | 11.5 | 4.8 | External hexagon | ‡ | Second check-up |
| 7 | Maxil. | Right | Premolar | 11.5 | 3.8 | Internal hexagon | ‡ | Third check-up |
| 8 | Maxil. | Left | Premolar | 11.5 | 3.8 | Internal hexagon | ‡ | Third check-up |
| 9 | Maxil. | Right | Molar | 11.5 | 5 | Internal hexagon | ‡ | |
| 10 | Maxil. | Left | Molar | 11 | 4 | Internal hexagon | † | |
| 11 | Maxil. | Right | Molar | 10 | 4.2 | Internal hexagon | ‡ | Third check-up |
| 12 | Maxil. | Right | Molar | 13 | 5 | Morse cone | ¶ | |
| 13 | Maxil. | Left | Molar | 13 | 3.5 | Morse cone | ¶ | |
| 14 | Maxil. | Left | Premolar | 11.5 | 3.5 | Internal hexagon | ‡ | |
| 15 | Maxil. | Left | Premolar | 11 | 4 | Morse cone | ¶ | Third check-up |
| 16 | Maxil. | Left | Premolar | 12 | 3.5 | Internal hexagon | § | |
| 17 | Maxil. | Right | Premolar | 13 | 3.5 | Internal hexagon | † | |
| 18 | Maxil. | Left | Molar | 10 | 4.1 | Internal hexagon | ‡ | |
| 19 | Maxil. | Right | Premolar | 11.5 | 4.1 | Internal hexagon | ‡ | |
| 20 | Maxil. | Left | Premolar | 15 | 4.6 | Internal hexagon | \| | |
| 21 | Maxil. | Right | Molar | 12 | 3.8 | Internal hexagon | § | |
| 22 | Maxil. | Right | Premolar | 11.5 | 3.8 | External hexagon | § | Second check-up |
| 23 | Maxil. | Left | Premolar | 12 | 3.5 | Internal hexagon | § | Second check-up |

*Mand. indicates mandibular; Maxil., maxillary.

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‡Avinent (Avinent Implant System, Lots 17680-17957-19573-19886-20888-21011-22885-27430, Barcelona, Catalonia, Spain).

§Microdent (Microdent Implant System, Lots 01920214-06560414-08390615-09410713-10500714, Barcelona, Catalonia, Spain).

|BioHorizons (BioHorizons, Lots 1503810-1504617, Birmingham, AL).

¶Neodent (Neodent/Straumann, Lot 800147177-800136351-800085202, Curitiba, Paraná, Brazil).

supraeruption in most cases.[2–4,16] This supraeruption seems to be greater in young people,[2] in people with decreased alveolar bone level,[4] in maxillary teeth,[16] and in females with high anterior face.[17] If the ISC does not contact with a natural antagonist tooth, supraeruption of the natural tooth may occur.

The main objective of this study was to assess whether the occlusal scheme at the intercuspal position of an ISC in molar and premolar regions varies 2 years after placement. We also aimed to explore the factors that could predict variation in the occlusal scheme.

## Methods

### *Population*

This prospective study was conducted at the Barcelona University Dental Hospital from February 2015 to December 2018. Patients were invited to participate if they were adults, had at least 20 natural teeth, required treatment with an ISC in the posterior region (from the first premolar to the second molar), and had no pathology that could affect normal masticatory function. Patients with incomplete records or those who received dental treatment during the study altering the occlusal scheme were excluded. All participants provided informed consent, and the study was approved by the Ethics Committee of the Barcelona University Dental Hospital (Code 2014-32). All experiments were carried out in accordance with the principles of the Helsinki Declaration.

### *Implant insertion surgery and restorative procedure*

Implant insertion was performed by experienced students in master's programs. Implant characteristics were selected according to individual clinical determinants (Table 1). Ninety days after implant insertion, the second surgery was carried out.

Impressions were obtained 15 days after the second stage procedure. The implant impressions were used to fabricate porcelain fused to metal ISCs using conventional procedures for screw-retained prostheses. Two weeks after the impressions were obtained, the ISCs were screwed in place with a torque gauge (25–30 Ncm) according to each manufacturer's instructions. Screw access openings were restored with compacted polytetrafluoroethylene and light cured composite.

All ISCs were then adjusted following current clinical recommendations.[10,11,13] Briefly, the crown was adjusted at intercuspal position using articulating paper (Bausch Articulating Paper, BK09 40 μm, Lot Number 77027, Köln, Germany) with contact at heavy clench or maximum bite force, and no contact at light clench or near half of the maximum force.[18,19] Occlusal contact was also adjusted in the central fossa of the opposing tooth. No contact was allowed during laterotrusion or protrusion on the ISCs.[10]

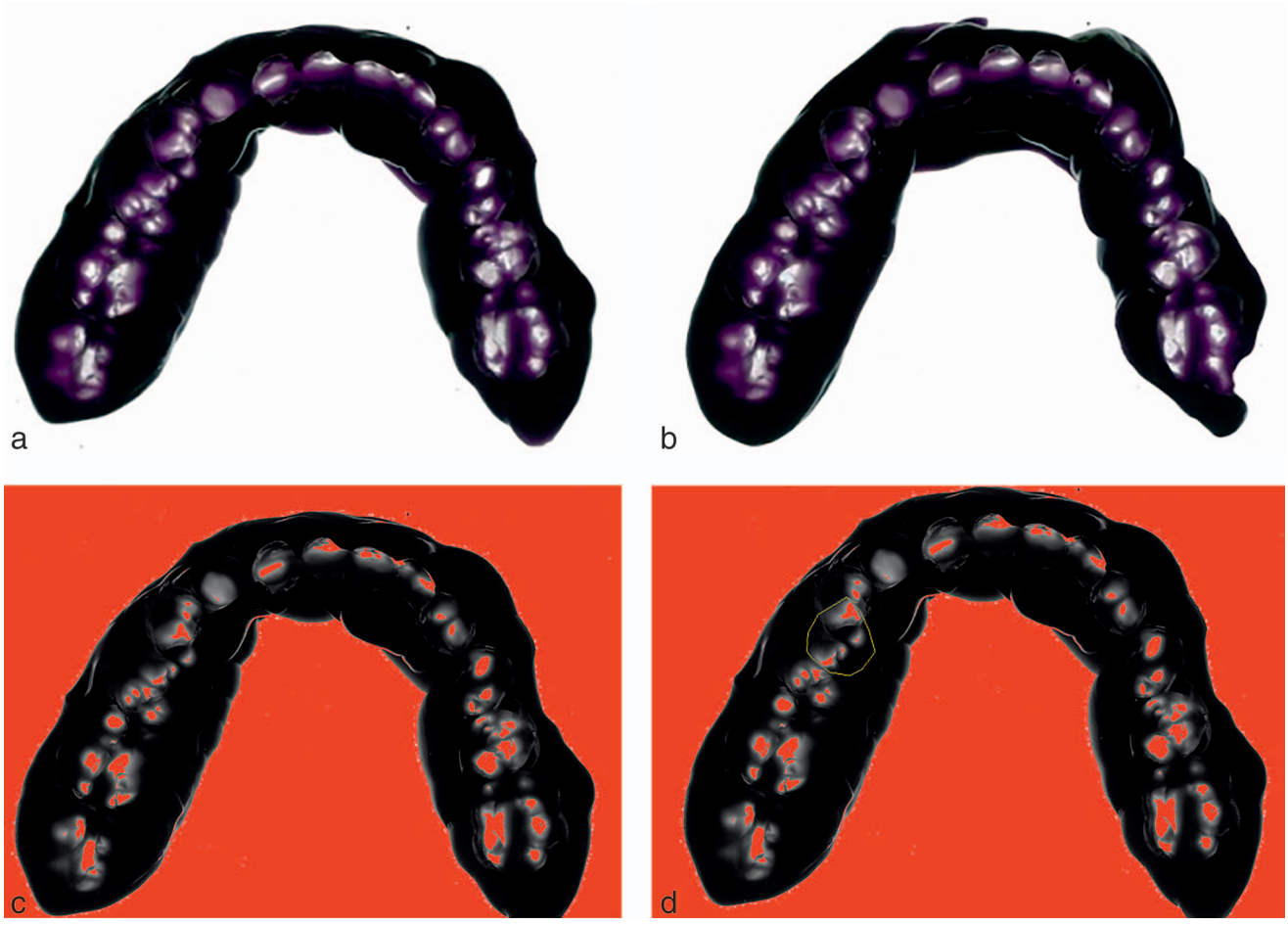


**Figure 1.** Occlusal scheme obtained with silicone bite registration at baseline. (a) Silicone bite registration by light clenching in a representative patient. (b) Silicone bite registration by heavy clenching in the same patient. (c) Occlufast was processed by ImageTool to determine the presence of contact. (d) Occlufast was processed by ImageTool to determine the occlusal contact area.

### *Data measurements*

Patient age and gender, as well as the position of the implant, were recorded. The vertical dimensions of the mid and lower face were measured to determine the anterior facial height.[20] Mobility of the antagonist tooth was assessed by 3 open-mouth measurements using the Periotest (Medizintechnik Gulden, Modautal, Germany), the measurements were averaged.[21] Vertical overlap was measured with a digital caliper (Absolute; Vogel Germany, Kevelaer, Germany). The chewing side preference was determined quantitatively by a visual analogue scale.[22]

The occlusal scheme was assessed 3 times by a single researcher: immediately after placing the ISCs, 6 months, and 2 years later. The occlusal relationship was recorded by 2 methods, each performed while participants were seated with the Frankfurt plane parallel to the floor.

The first method was a silicone maxillomandibular relationship record, which comprised 2 techniques depending on the intensity of clenching. Two records were each obtained in the intercuspal position for 1 minute, one while applying light clenching (near half of the maximum force) and the other while applying maximum force. For each registration, Occlufast Rock (Zhermack, Lot Number 242096, Badia Polesine, Italy) was applied to all mandibular tooth surfaces. The occlusal registration was trimmed, scanned, and analyzed by computer software (UTHSCSA Image Tool software, 3.0 University of Texas Health Science Center, San Antonio, TX). To establish the equivalence between the thickness of the occlusal record and each of the 256 grey levels, a stepped wedge of Occlufast was used and measured with a digital external caliper (IP40; Vogel Germany) (Figure 1a and b). The presence or absence of occlusal contact was determined in the following 3 regions: in the ISC, in the adjacent tooth, and in the contralateral tooth; considering an interocclusal distance of 0–200.[23–26] The occlusal contact area between the ISC and its antagonist was measured considering contact an interocclusal distance of 0–500 μm (Figure 1c and d).[23]

The second method used to record the occlusal relationship was the T-Scan III (Tekscan, Inc, Boston, MA). After selecting the size of the sensor and measuring the width of the right maxillary central incisor, the sensitivity was calibrated. Each participant was instructed to open and close his or her mouth in an intercuspal position with maximum force, while a 100-μm thick sensor foil was placed intraorally. The T-Scan software then generated a dynamic report showing the

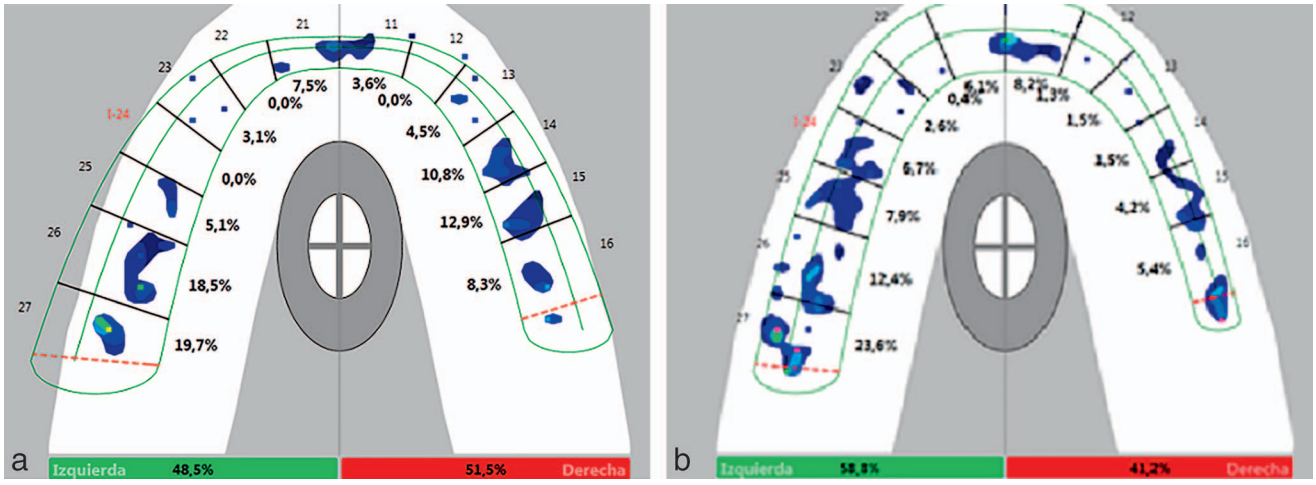


**Figure 2.** Occlusal scheme obtained with T-Scan. (a) T-Scan record obtained during light clenching. (b) T-Scan record obtained during heavy clenching. The display shows the relative force on implant area (first upper left premolar), which is highlighted in red.

occlusal picture of the relative bite force. From this dynamic report, 1 image for the 2D occlusal picture at maximum force and 2 other images at nearly 50% of the maximum force were selected.[27] For each image, the presence or absence of occlusal contact was determined around the implant crown, in the adjacent tooth, and in the contralateral tooth. The relative percentage of the total force exerted on each tooth was recorded for occlusal contact (Figure 2a and b).[28]

The possible migration of the adjacent teeth to the crown on implants was assessed at the 2-year check-up. The interproximal space at mesial and at distal ends of the ISC were measured by the number of 30 μm thickness matrix bands (KerrHawe SA, Lot Number 2556462, Bioggio, Switzerland) that could be inserted.[21]

### *Statistical analysis*

The focus of the analysis was the ISC. To determine whether the occlusal scheme varies 6 months and 2 years after ISC placement, the presence of occlusal contact was assessed using silicone record at maximal bite force and considering a 0–200 μm interocclusal gap. Qualitative differences in the presence of occlusal contact on the ISC, on the adjacent tooth, and on the contralateral tooth before and 6 months or 2 years after placement were assessed using the McNemar test.

Change in the occlusal scheme was assessed quantitatively using 2 methods. First, we used the occlusal contact area of the ISC, given an interocclusal distance of 0–500 μm, using silicone record under maximal bite force. Second, we used the relative percentage of the total force exerted to the ISC, as measured by the T-Scan. Occlusal registration and T-Scan are valid and reliable methods for measuring occlusal contact area in dentate individuals.[27] For both methods, differences between measurements at placement and 2 years were calculated, confirmed for normality using the Kolmogorov–Smirnov test, and analyzed by 1-sample *t* test.

Finally, 2 mixed-design analysis of variance models were performed to explore whether between-subject factors (eg, age, gender, implant position, masticatory laterality, mobility of antagonist tooth, vertical overlap, and anterior facial height) and within-subject variables (eg, time, region, method, and technique) significantly explained the variance in occlusal contact area or the percentage of force. Statistical analysis was performed using the IBM SPSS version 24.0 (IBM Corp, Armonk, NY) and $P$ values $< .05$ were considered statistically significant. The methodology was reviewed by an independent statistician.

## Results

Thirteen men and 7 women (mean age, 57.4 years; SD, 15 years; range, 32–78 years) were initially included in this study. In total, 23 implants were inserted; 3 participants each received 2 implants. However, 3 patients were excluded in the 6-month follow-up: 2 who did not attend the check-up and 1 whose data were incorrectly recorded (Table 1). Three more patients were excluded in the 2-year follow-up: 1 with 2 implants because the antagonist teeth of the implants studied were extracted and the other 2 because they refused to attend the check-up. Therefore, we assessed 20 ISCs in 17 patients at the 6-month follow-up time point and 16 ISCs in 14 patients at 2 years. The locations of implant placement are shown in Table 1. The 14 patients included in this study had a mean vertical overlap of 2.3 mm (SD, 1.6 mm); facial height was medium in 7, long in 6 and short in 1. Three participants chewed mainly on their left, 7 chewed centrally or alternatively, and 4 chewed mainly on their right. The mean Periotest value of the 16 ISC antagonist tooth was 1.0 (SD, 5.9).

At 2 years, the qualitative variations in occlusal contact assessed by silicone record applying maximum clenching are shown in Table 2 for the ISCs and control teeth. Among the ISCs, there were no changes in 11 crowns (8 with contact and 3 without contact). However, there were changes in 5 ISCs, with contact appearing in 2 and disappearing in another 3 ($P = 1$; McNemar test). In the control teeth, the occlusal pattern changed in 3 cases in the adjacent teeth and in 1 in the contralateral tooth at 2 years ($P = 1$; McNemar test). When

TABLE 2

Qualitative variation in occlusal contacts for implant-supported single crowns and control teeth 2 years after placement

| | Occlusal Contact After 2 Years | |
|---|---|---|
| | Absent | Present |
| Implant-supported single crown | | |
| Occlusal contact at baseline | | |
| Absent | 3 | 2 |
| Present | 3 | 8 |
| Adjacent control tooth | | |
| Occlusal contact at baseline | | |
| Absent | 2 | 1 |
| Present | 2 | 11 |
| Contralateral control tooth | | |
| Occlusal contact at baseline | | |
| Absent | 2 | 0 |
| Present | 1 | 13 |

occlusal contact was assessed by T-Scan, occlusal scheme variation was similar to that observed by silicone record, though more occlusal contacts were detected. When occlusal contact was assessed by applying light clenching, fewer occlusal contacts were detected, regardless of the method used. Overall, occlusal contact was less common in the ISCs than in either the ipsilateral or contralateral controls. Few occlusal contacts appeared or disappeared between baseline and 6 months and between 6 months and 2 years, and the differences were not significant ($P = 1$; McNemar test).

When the occlusal relationship was assessed quantitatively as the occlusal contact area, no significant variation was observed 2 years after ISC placement (mean difference, −1.5 $mm^2$; 95% CI, −5.5 to 2.4 $mm^2$). When the occlusal scheme was assessed quantitatively as a percentage of force applied to the ISC by T-Scan III, no significant variation ($P = .27$; paired $t$ test) was observed 2 years after ISC placement (mean difference, −1.4%; 95% CI, −1.2% to 4.0%).

The mixed-design analysis of variance models showed that neither age, gender, implant position, masticatory laterality, antagonist tooth mobility, vertical overlap nor anterior facial height affected the occlusal scheme variation 2 years after ISC placement.

The interproximal space measured at 2 years check-up did not differ significantly between the mesial (mean, 0.12 mm; SD, 0.10) and the distal part (mean, 0.12 mm; SD, 0.11) ($P = .72$ Wilcoxon test).

## Discussion

Assessing occlusal contact by silicone record and T-Scan III under light and heavy clenching 2 years after ISC placement, there was no qualitative or quantitative variation in the occlusal scheme of patients. These results were also confirmed by comparison with the occlusal scheme of 2 control teeth. Although a few occlusal changes were detected, most of them were in both directions and could reasonably be attributed to measurement error. We therefore conclude that a valid scheme for occlusal adjustment after ISC placement is to ensure no contact under light clenching, and contact under maximum clenching. This approach appears suitable for avoiding tooth migration.

If the ISC meets a natural tooth that acts as an antagonist, supraeruption of the natural tooth could occur. Vertical tooth movement adjacent to ISCs in the anterior maxilla has been reported 4–15 years after placement.[17,29] However, the study periods were different in these studies, and it is known that the anterior teeth are more likely to migrate than the posterior teeth. In the present study, quantitative demonstration of a lack of supraeruption of the posterior teeth suggests that further occlusal change is unlikely in this area.

With regard to horizontal migration, variation was observed from the moment of crown placement (both mesially and distally to the ISC), but there is no clear tendency toward migration in the adjacent teeth. A previous study determined that the mesial migration of natural teeth adjacent to fixed prostheses on implants increases progressively with time; it is especially significant 5 years after the placement of the prosthesis, is greater in bridges on implants than in unit crowns, and especially affects elderly patients or teeth with high Periotest values.[21] These differences in the results may be attributed to methodological differences and characteristics of the sample.

There are 4 possible explanations for the lack of change in the occlusal scheme. We observed that 18 of the 20 antagonist teeth had contact not only with the ISCs but also with the teeth adjacent to them. It is possible that this may avoid supraeruption of the natural antagonist teeth and offer greater occlusal stability. Further study is needed using implant-fixed partial prostheses with more than 2 units to confirm this hypothesis and to assess the supraeruption of the natural antagonist tooth, which would only be in contact with the implant prosthesis. Another reason for the lack of supraeruption could be that occlusal contact occurs when clenching with maximum force. It is known that most people use heavy force not only for functional chewing but also for parafunctional clenching or grinding. Furthermore, we cannot disregard the fact that a slight supraeruption will be countered by slight wear. In fact, the wear of the natural antagonist tooth by friction against ISC ceramics may be more than 40 μm/year.[30] Finally, supraeruption is also related to poor periodontal support,[4] most patients in this study had good periodontal support, as demonstrated with the Periotest.

The occlusal scheme recommended by the current guidelines is valid to avoid tooth migration and protect implants from overloading and biomechanical complications.[10,13] The occlusal contact area in the intercuspal position, is positively related to masticatory performance,[23,26] and the side with the larger contact area is more likely to be used for chewing.[24,31] Because the occlusal contact area may differ under medium and high clenching forces, this occlusal scheme may allow less masticatory function. This issue should be assessed in a further study.

The small sample size, a large number of drop-out cases, the use of a convenience sampling, and a possible volunteer bias sampling may be considered limitations of this study and some caution is needed regarding generalizations of these

findings. Moreover, the 2-year follow-up could be considered a short period of time having in mind that these restorations would have clinical service for decades. However, it is during the first years after being placed that the major effect of the occlusal scheme on the tooth migration is expected. Finally, the fact that all ISCs were adjusted using the same protocol, but that some occlusal records exhibited contact while others did not, seems contradictory. However, although articulating paper is most often used to adjust occlusal contacts in clinical settings, the method is subjective and prone to associated errors.[32–34] Moreover, the thickness of the articulating paper (40 μm) may have affected the occlusal records given that occlusal contacts were recorded at 200 μm and 100 μm for the silicone record and T-Scan methods, respectively. Despite these limitations, the study had several strengths. Occlusal contacts were assessed quantitatively and qualitatively in the ISCs and in 2 teeth as controls.

## Conclusion

In this preliminary study, the occlusal scheme at intercuspal position did not significantly vary 2 years after placing an ISC in a molar or premolar region.

## Abbreviation

ISC: implant-supported single crown

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## References

1. Friedman PK, Lamster IB. Tooth loss as a predictor of shortened longevity: exploring the hypothesis. *Periodontol 2000*. 2016;72:142–152.

2. Kiliaridis S, Lyka I, Friede H, et al. Vertical position, rotation, and tipping of molars without antagonists. *Int J Prosthodont*. 2000;13:480–486.

3. Faggion CM, Giannakopoulos NN, Listl S, et al. How strong is the evidence for the need to restore posterior bounded edentulous spaces in adults? Grading the quality of evidence and the strength of recommendations. *J Dent*. 2011;39:108–116.

4. Lindskog-Stokland B, Hansen K, Tomasi C, et al. Changes in molar position associated with missing opposed and/or adjacent tooth: a 12-year study in women. *J Oral Rehabil*. 2012;39:136–143.

5. Albrektsson T, Donos N. Implant survival and complications. The third EAO consensus conference 2012. *Clin Oral Implants Res*. 2012;23(suppl 6):63–65.

6. Pjetursson BE, Bragger U, Lang NP, et al. Comparison of survival and complication rates of tooth-supported fixed dental prostheses (FDPs) and implant-supported FDPs and single crowns (SCs). *Clin Oral Implants Res*. 2007;18(suppl 3):97–113.

7. Lewis MB, Klineberg I. Prosthodontic considerations designed to optimize outcomes for single-tooth implants. A review of the literature. *Aust Dent J*. 2011;56:181–192.

8. Chambrone L, Chambrone LA, Lima LA. Effects of occlusal overload on peri-implant tissue health: a systematic review of animal-model studies. *J Periodontol*. 2010;81:1367–1378.

9. Hsu YT, Fu JH, Al-Hezaimi K, et al. Biomechanical implant treatment complications: a systematic review of clinical studies of implants with at least 1 year of functional loading. *Int J Oral Maxillofac Implants*. 2012;27:894–904.

10. Kim Y, Oh TJ, Misch CE, et al. Occlusal considerations in implant therapy: clinical guidelines with biomechanical rationale. *Clin Oral Implants Res*. 2005;16:26–35.

11. Gross M. Occlusion in implant dentistry. A review of the literature of prosthetic determinants and current concept. *Aust Dent J*. 2008;53(suppl 1): 60–68.

12. Koyano K, Esaki D. Occlusion on oral implants: current clinical guidelines. *J Oral Rehabil*. 2015;42:153–156.

13. Klineberg IJ, Trulsson M, Murray M. Occlusion on implants – Is there a problem? *J Oral Rehabil*. 2012;39:522–537.

14. Humphrey S. Implant maintenance. *Dent Clin North Am*. 2006;50: 463–478.

15. Todescan S, Lavigne S, Kelekis-Cholakis A. Guidance for the maintenance care of dental implants: clinical review. *J Can Dent Assoc*. 2012;78:c107.

16. Craddock HL, Youngson CC, Manogue M, et al. Occlusal changes following posterior tooth loss in adults. Part 1: a study of clinical parameters associated with the extent and type of supraeruption in unopposed posterior teeth. *J Prosthodont*. 2007;16,485–494.

17. Jemt T, Ahlberg G, Henriksson K, et al. Tooth movements adjacent to single-implant restorations after more than 15 years of follow-up. *Int J Prosthodont*. 2007;20:626–632.

18. Caro AJ, Peraire M, Martinez-Gomis J, et al. Reproducibility of lateral excursive tooth contact in a semi-adjustable articulator depending on the type of lateral guidance. *J Oral Rehabil*. 2005;32:174–179.

19. Martínez-Gomis J, Willaert E, Nogues L, et al. Five years of sleep apnea treatment with a mandibular advancement device. Side effects and technical complications. *Angle Orthod*. 2010;80:30–36.

20. Heij DG, Opdebeeck H, van Steenberghe D, et al. Facial development, continuous tooth eruption, and mesial drift as compromising factors for implant placement. *Int J Oral Maxillofac Implants*. 2006;21:867–878.

21. Wong AT, Wat PY, Pow EH, et al. Proximal contact loss between implant-supported prostheses and adjacent natural teeth: a retrospective study. *Clin Oral Implants Res*. 2015;26:e68–e71.

22. Flores-Orozco EI, Rovira-Lastra B, Peraire M, et al. Reliability of a visual analog scale for determining the preferred mastication side. *J Prosthet Dent*. 2016;115:203–208.

23. Lujan-Climent M, Martinez-Gomis J, Palau S, et al. Influence of static and dynamic occlusal characteristics and muscle force on masticatory performance in dentate adults. *Eur J Oral Sci*. 2008;116:229–236.

24. Martinez-Gomis J, Lujan-Climent M, Palau S, et al. Relationship between chewing side preference and handedness and lateral asymmetry of peripheral factors. *Arch Oral Biol*. 2009;54:101–117.

25. Rovira-Lastra B, Flores-Orozco EI, Salsench J, et al. Is the side with the best masticatory performance selected for chewing? *Arch Oral Biol*. 2014; 59:1316–1320.

26. Flores-Orozco EI, Rovira-Lastra B, Willaert E, et al. Relationship between jaw movement and masticatory performance in adults with natural dentition. *Acta Odontol Scand*. 2016;74:103–107.

27. Ayuso-Montero R, Mariano-Hernandez Y, Khoury-Ribas L, et al. Reliability and validity of T-scan and 3D intraoral scanning for measuring the occlusal contact area. *J Prosthodont*. 2020;29(1):19–25.

28. Roque MA, Gallucci GO, Lee SJ. Occlusal pressure redistribution with single implant restorations. *J Prosthodont*. 2017;26:275–279.

29. Bernard JP, Schatz JP, Christou P, et al. Long-term vertical changes of the anterior maxillary teeth adjacent to single implants in young and mature adults. A retrospective study. *J Clin Periodontol*. 2004;31:1024–1028.

30. Yip KH, Smales RJ, Kaidonis JA. Differential wear of teeth and restorative materials: clinical implications. *Int J Prosthodont*. 2004;17:350–356.

31. Rovira-Lastra B, Flores-Orozco EI, Ayuso-Montero R, et al. Peripheral, functional and postural asymmetries related to the preferred chewing side in adults with natural dentition. *J Oral Rehabil*. 2016;43:279–285.

32. Carey JP, Craig M, Kerstein RB, et al. Determining a relationship between applied occlusal load and articulating paper mark area. *Open Dent J*. 2007;1:1–7.

33. Qadeer S, Kerstein R, Kim RJ, et al. Relationship between articulation paper mark size and percentage of force measured with computerized occlusal analysis. *J Adv Prosthodont*. 2012;4:7–12.

34. Kerstein RB, Radke J. Clinician accuracy when subjectively interpreting articulating paper markings. *Cranio*. 2014;32:13–23.