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Effects of impression material and implant angulation on the impression accuracy of external connection implants: An in vitro study

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EFFECTS OF IMPRESSION MATERIAL AND IMPLANT ANGULATION ON THE IMPRESSION ACCURACY OF EXTERNAL CONNECTION IMPLANTS: AN *IN VITRO* STUDY

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Abstract

A precise impression is mandatory to obtain passive fit in implant-supported prostheses. The aim of this study was to evaluate the effect of impression material and implant angulation on the impression accuracy of external-connection implants. Four customized epoxy resin master models, with two-implant analogs placed parallel or with different degrees of divergence (10, 20 and 30 degrees), were fabricated with their corresponding passively fitted reference frameworks. Ten impressions were taken, for each model, with vinyl polysiloxane (VPS) and polyether (PE) using custom open tray impression technique. Impressions were poured with type IV dental stone and vertical discrepancies between the reference frameworks and the platforms of the implant replicas were evaluated, with a stereo video microscope, applying the one-screw test. The data were analyzed using two-way ANOVA, Sidak, and one-sample t-test at $p \leq 0.05$. No significant differences were found between PE and VPS at various angulations ($p > 0.05$). However, all groups showed a significant difference ($p < 0.05$) when compared to their true values. Within the limitations of this study, impression material and implant angulation had no significant effect on impression accuracy of external connection implants.

Keywords: Implant impression - impression accuracy - external connection implants - impression material - implant angulation - marginal gap - vertical misfit.

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EFFETS DU MATÉRIAU D'EMPREINTE ET DE L'ANGULATION DE L'IMPLANT SUR LA PRÉCISION DE L'EMPREINTE DES IMPLANTS À CONNEXION EXTERNE: UNE ÉTUDE IN VITRO

Résumé

Afin d'obtenir une insertion passive des prothèses implanto-supportées, une empreinte précise est obligatoire. L'objectif de cette étude était d'évaluer l'effet du produit d'empreinte et de l'angulation de l'implant sur la précision de l'empreinte dans le cas d'implants à connexions externes. Quatre maîtres modèles, conçus sur demande en résine époxy, avec deux analogues positionnés parallèles ou avec différents degrés de divergence (10, 20 et 30 degrés), ont été fabriqués avec leurs infrastructures respectives à insertion passive. Dix empreintes ont été prises, pour chaque maître modèle, avec le vinyle polysiloxane (VPS) et le polyéther (PE) tout en adoptant la technique directe avec des portes-empreintes individualisées. Les empreintes ont été ensuite coulées avec du plâtre type IV et les défauts d'adaptation à composante verticale entre l'infrastructure de référence et la plateforme de l'analogue ont été évalués, avec un stéréo vidéo microscope, en optant pour le test à une seule vis. Les données ont été analysées en utilisant l'ANOVA à deux-facteurs, Sidak et le test de Student pour échantillon unique avec $p \leq 0.05$. Les résultats ont montré l'absence d'une différence significative entre PE et VPS quelle que soit l'angulation ($p > 0.05$). Cependant, les groupes ont montré une différence significative en comparaison avec la valeur réelle ($p < 0.05$). Tout en considérant les limitations de l'étude, le produit d'empreinte et l'angulation de l'implant n'ont pas d'effet sur la précision de l'empreinte en cas d'implants à connexions externes.

Mots clés: empreinte implantaire - implants à connexions externes - produit d'empreinte – angulation – hiatus - défaut d'adaptation verticale.

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Introduction

Oral rehabilitation of partial and complete edentulism with osseointegrated implants has presently become the treatment of choice in daily clinical practice. While acknowledging the fact that implants lack the inherent physiological mobility of teeth, passive fit becomes more critical in implant supported prosthesis [1].

Theoretically, a passively fitted framework should induce absolute zero strain on the supporting implant components and the surrounding bone, in the absence of an applied external load [2]. However, obtaining an absolute passive fit may not be achievable since an inevitable degree of inaccuracy would always be present [3]. Henceforth, the arisen of the "clinically acceptable fit" concept which can be defined as a clinically acceptable level of contact, where the stress conditions fall within physiological limits and remain the same after inserting the prosthesis [4]. Many authors have attempted to quantify acceptable fit of implant frameworks, although no universal guidelines have been established [2, 5]. It has been speculated that marginal discrepancies of 10 µm [6] to 150 µm [7] would be clinically acceptable.

An ill-fitting prosthesis generates potentially detrimental stresses within the prosthesis-implant-bone complex, which may lead to mechanical more than biological complications, thus jeopardizing the long-term success of implants and implant-supported prosthesis [8]. Mechanical complications include occlusal discrepancies, screw loosening, bending and fracturing of the prosthetic or implant components [9, 10]. Furthermore, marginal misfit might enhance plaque accumulation, affecting soft and/or hard tissues around the implants [10]. As for biologic complications, the effect of misfit on the bone tissue around the implants remains controversial [11]. On the other hand, the definition of passive fit from a biomechanical perspective [2, 12] and the association between the degree of misfit and mechanical or biologic complications is yet to be established [13].

The passive fit is a result of an accurate working cast, which further depends on the accuracy of the impression procedure. Hence, the first and critical step to achieve a passively fitting prosthesis is an accurate three-dimensional transfer of the intraoral relationship between implants, teeth and adjacent structures through the impression procedure [9].

To date, several impression techniques and materials have been proposed to achieve an accurate master cast that will ensure an acceptable fitting prosthesis. The most common techniques are the indirect (transfer, closed tray) and the direct (pick-up, open tray), while the most used impression materials are polyether (PE) and vinyl polysiloxane (VPS) [14]. On the other hand, various assessment methods have been used to evaluate impression accuracy including linear distortion of the implant (or abutment) head positions, angular distortion of the implant (or abutment) long axis, gap distances between the master framework and replicas in test models, and the amount of strain produced in a master framework [15].

In addition, different factors may affect the accuracy of implant impressions and/or the resulting casts, namely impression tray, impression level, impression material, impression technique (direct/indirect, splinted/non-splinted), splinting material, number of implants, implant depth, coping design, coping modification, time delay for stone pouring, pouring technique, die material or stone material accuracy and machining tolerance of prosthetic components [1,14-17].

Angulation of dental implants is another factor affecting the accuracy of the impressions and the resulting master casts [1, 14-17]. This lack of parallelism among the implants, and between the implants and the teeth, are commonly encountered in clinical situations, due to anatomical limitations or esthetic considerations [18]. Numerous studies have investigated the effect of non-parallel implants, at different degrees of divergence or convergence, on the accuracy of impressions in partially edentulous situations [8-10, 18-35]. However, there is a scarce data, with inconsistent results, regarding the accuracy of impression materials in angulated implants [10, 18, 20, 31-33].

The aim of this in-vitro study was to investigate the accuracy of two different impression materials (PE, VPS) in models simulating parallel and angulated (10°, 20° and 30°) implants. The null hypothesis was that the impression material and implant angulation would have no effect on the accuracy of the impressions.

Materials and methods

Fabrication of the master models

Four customized epoxy resin models (4 cm wide, 3 cm length and 2 cm deep) were manufactured to serve as the master models. Two implant analogs (4.1 mm × 12 mm; Neodent, São Paulo, Brazil) with an external connection were set aside to simulate a partially edentulous cast.

To place the implant analogs, two holes (4.2 mm wide × 10 mm deep) were drilled in each of the 4 master models and the implant analogs were affixed to each hole with epoxy adhesive (UHU Epoxy Ultra Strong). The distance between the replicas' platforms was 15 mm from center to center. In addition, the platforms of the implant analogs were placed 2 mm coronal to the horizontal surface (Fig 1).

The first analog (Analog 1) was placed perpendicular to the horizontal plane (0 degrees) while the other (Analog 2) was placed either parallel to the first (0 degrees) or at an angle of 10, 20, or 30 degrees to the vertical plane (Fig. 2).

Model 1: Analog 1 and analog 2 were positioned parallel to each other and perpendicular to the horizontal plane.

Model 2: Analog 1 was positioned parallel with the vertical plane and

Fig. 1: Representation of the master models.

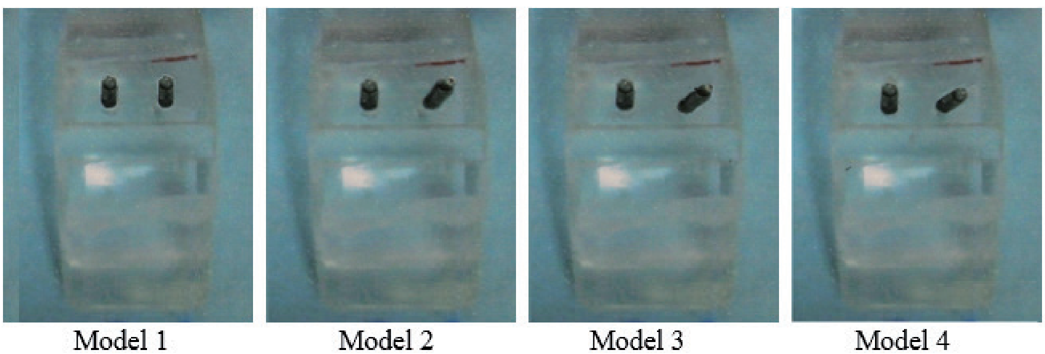

Fig. 2: Epoxy resin master models with parallel and angulated implants.

analog 2 was placed at a 10 degree angulation distal to the first analog.

Model 3: Analog 1 was positioned parallel with the vertical plane and analog 2 was placed at a 20 degree angulation distal to the first analog.

Model 4: Analog 1 was positioned parallel with the vertical plane and analog 2 was placed at a 30 degree angulation distal to the first analog.

Fabrication of custom trays

The master cast, which had the pick-up impression copings (pick-up impression copings, Neodent), was duplicated from the master model.

To standardize the tray position and allow a uniform thickness of the impression material, ten customized open impression trays, with 3 mm wax relief and 2 stops, were made for each master cast making a total of 40 custom trays. The custom impression trays were made using light-polymerizing acrylic tray resin (Silatray, Siladent Dr Böhme & Schöps GmbH, Germany) and cured in a universal light polymerisation unit (Polylux-P / PT, Dreve Dentamid GmbH, Germany) for a total of 8 minutes. Afterwards, occlusal windows were plunge cut in the trays, above the impression copings, to allow access to the guide pins.

Impression procedures

A total of 40 impressions were made using vinyl polysiloxane (Express Heavy / Light body, 3M ESPE, Seefeld, Germany) and polyether (Impregum Penta Soft, 3M ESPE, Seefeld, Germany) as the impression materials. Ten impressions were made on each master model (five for each impression material).

Prior to the impression procedure, the impression copings were abraded with 50µ aluminum oxide (Siladent Dr Böhme & Schöps GmbH, Germany), then tightened to the implant analogs with a torque wrench calibrated at 10 Ncm. Furthermore, impression copings and custom trays were coated with the appropriate tray adhesive (VPS Tray Adhesive or Polyether Adhesive, 3M ESPE, Seefeld, Germany) and allowed to dry for 15 minutes according to the manufacturer's instructions.

Subsequent to the tray adhesive application, the heavy body impression material was machine-mixed (Pentamix 3, 3M ESPE, Seefeld, Germany) and loaded into the custom trays whereas the light body impression material was meticulously syringed around the impression copings using an auto-mixing cartridge. The impression trays were seated on the master models with finger pressure and the impressions were allowed to polymerize for 12 minutes at room temperature.

After loosening the guide pins of the impression copings, the impressions were separated from the master models. If any inaccuracy, such as air voids, impression material between the analog-impression coping interface, impression material separation from the custom tray, or nonhomogeneous mix of materials was detected, the impression would be repeated.

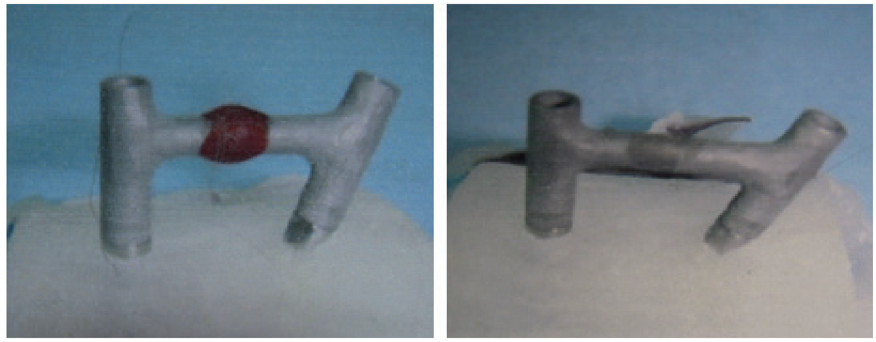

Fig. 3: Reference frameworks designed and adjusted directly on the master models.

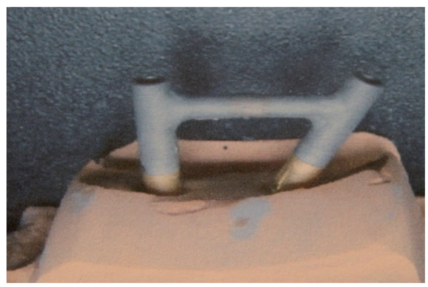

Fig. 4: Reference framework fitting on experimental casts.

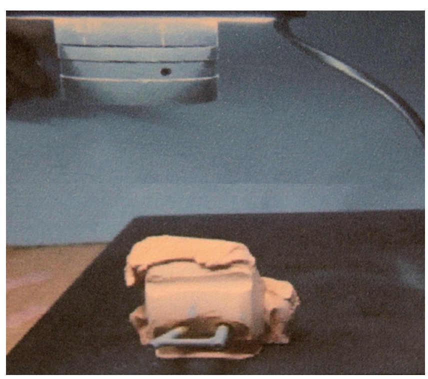

Fig. 5: Vertical misfit evaluation.

Fabrication of experimental casts

Implant analogs (101.003, Neodent) were connected to the impression copings embedded in the impression material. To mimic the clinical situation, a soft tissue cast of 2 mm thickness was made around the analogs with vinyl polysiloxane impression material (Gingifast Elastic, Zhermack). After 60 minutes, the impressions were poured with vacuum mixed type IV dental stone (GC Fujirock EP, GC Corp) in accordance with the manufacturer's instructions. The master casts were separated from the impressions 120 minutes later and labeled prior to measurements. Through these procedures, 40 casts were obtained.

Fabrication of the reference frameworks

Four screw-retained reference frameworks, simulating a bar attachment prosthesis, were designed on each epoxy resin master model. The frameworks were waxed on two non-hexed UCLA abutments (Cobalt-Chromium abutment, Neodent, São Paulo, Brazil). Patterns were sprued and invested in a phosphate-bonded investment (GC Fujivest II). Following burnout, the investment rings were cast in a Cobalt-Chromium alloy (Remanium GM 800+, Dentaurum).

After casting, the frameworks were screwed to the implant analogs in the master models and inspected with a stereo video microscope (GR001+130BCM, Shanghai, China) at X47 magnification for the first abutment/implant interface observation (post-casting examination). To eliminate potential errors introduced during casting and minimize the marginal gap, the bars were sectioned in the middle using a carborundum disk mounted on a mandrel. To ensure an acceptable passive fit of 10 µm, the two sectioned components were properly oriented under microscope magnification (X47) and joined using a self-curing resin (Duralay, GC Pattern resin). A heat stopper (Thermostop, Bego GmbH & Co. KG, Germany) was applied on the master models then the bars were torch-soldered using a low fusing solder (Fig. 3).

Measurement of accuracy

After achieving a passively fitting framework in the master models, the soft tissue analog was removed and the reference frameworks were seated on the experimental casts to assess the accuracy of the impressions (Fig. 4).

For this purpose, one screw was tightened to each of the perpendicular analog (Analog 1) using a torque wrench calibrated at 10 Ncm and vertical misfit measurements were recorded at the opposite analog (Analog 2). The vertical misfit, in micrometers, was assessed by measuring the gap between the lower external margin of the reference frameworks and the upper external margin of the implant replicas, using a stereo video microscope under X47 magnification (Fig. 5).

The experimental casts were placed in a standardized position (90mm away from the microscope) and photos of the mesial and distal sides, focusing on two previously marked points at the highest contour, were taken for each duplicated cast. Afterwards, the images were analyzed using UTHSCSA

Impression material-Implant divergence	N	Vertical misfit (μm) in experimental casts		P*
		Mean	SD	
PE-0°	5	25.578	8.015	0.423
VPS-0°	5	28.834	6.947	
PE-10°	5	22.787	6.71	0.586
VPS-10°	5	20.579	5.061	
PE-20°	5	20.926	5.329	0.606
VPS-20°	5	23.019	4.06	
PE-30°	5	26.159	8.181	0.666
VPS-30°	5	24.412	4.742	

Table 1: Vertical misfit measurements according to impression material and implant divergence.

N, sample size; SD, standard deviation; PE, polyether; VPS, vinyl polysiloxane; *Differences between both materials were evaluated by analysis of variance, p ≤ 0.05 level was considered significant.

Impression material-Implant divergence	Test value = 10 μm			
	Mean Difference	P value	95% Confidence Interval	
			Lower	Upper
PE-0°	15.58	0.012*	5.63	25.53
VPS-0°	18.83	0.004*	10.21	27.46
PE-10°	12.79	0.013*	4.45	21.12
VPS-10°	10.58	0.009*	4.29	16.86
PE-20°	10.93	0.01*	4.31	17.54
VPS-20°	13.02	0.003*	7.30	18.74
PE-30°	16.16	0.012*	6.00	26.32
VPS-30°	14.41	0.002*	8.52	20.30

Table 2: One sample t-test for comparisons with the test value.

PE: Polyether; VPS: Vinyl polysiloxane; *Significant at p ≤ 0.05.

ImageTool software (Evans Technology Inc., Roswell, GA, USA).

Statistical analysis

SPSS computer software (SPSS 18.0, Inc; Chicago, IL) was used to analyze the data. The Kolmogorov–Smirnov test was performed to verify the normality of the data distribution. Multivariate two-way analysis of variance (ANOVA) was undertaken to determine whether significant differences existed among the groups. The considered variables were the type of impression material (PE, VPS) and the angulation of the implants (0°, 10°, 20° and 30°). Post hoc comparisons were conducted using the Sidak test. Furthermore, one sample t-test was used to compare the experimental groups with the master models. A significant difference is assumed to exist among the groups if the probability of such a difference is found to be ≤ 5% (p ≤ .05).

Results

Mean values and standard deviations of vertical misfit, stratified by impression material and degree of implant divergence are shown in Table 1. The statistical analysis of the data obtained in this study revealed that impression material and implant angulation had no significant effects on the vertical misfit values.

The mean vertical misfit ranged from 20.579 to 28.834 μm (Table 1). Two-way ANOVA revealed no statistically significant difference in misfit values, among different degrees of implant divergence (0, 10, 20, and 30 degrees), between PE and VPS impression material (p > 0.05). The experimental groups were then analyzed with a post hoc Sidak test. Regardless of the impression material, there was no significant difference between different implant angulations ($p > 0.05$; Table 3). In contrast, the data analyzed through one-way t-test showed significant differences from their true values ($p < 0.05$; Table 4).

Discussion

In implant dentistry, the passive fit achievement is a prerequisite for the implant survival and success [5]. Nonetheless, to achieve a passive seating of the prosthesis, the accuracy of the definitive cast, which in turn depends on the accuracy of the implant impression procedure is crucial [36].

Interestingly, there is no unanimous consensus regarding the most accurate combination of impression technique and material for angulated implants [20]. In previous studies, the direct impression technique was found to be as accurate as the indirect [9, 22, 25] while other studies indicated the superiority of the direct technique [20, 26, 28-31]. Furthermore, the necessity of splinting the impression copings has been controversial in external-connection implant systems [19-21, 24]. On the other hand, Vigolo et al. demonstrated that abraded and coated impression copings result in a more accurate master cast, as it seems that modified impression copings reduce the freedom of movement of the copings inside the impression material during clinical and laboratory procedures [37,38]. Therefore, in the present study, a direct non-splinted impression technique with modified impression copings was adopted.

Regarding the direct technique, an impression material should exhibit an adequate rigidity, in order to hold the impression copings thus preventing incidental displacements and ensure a minimal distortion between the laboratory components. Both polyether and addition VPS materials were found to meet the previously mentioned prerequisites [10, 39].

Although various methods have been used to evaluate impression accuracy [15], the present investigation compared the accuracy of impression materials at various angulations using the gap assessment method. Hence, the vertical marginal discrepancy between the implant replica and the framework interface for each experimental cast were assessed microscopically applying the one screw test. The measurement data was obtained at the posterior unscrewed end, while the anterior end was secured and preloaded to 10 Ncm. It has been stated that higher torque values were not advocated for multiple trial fitting of the reference frameworks in the experimental casts. Consequently, the lowest torque available with the manufacturer's torque driver (10 Ncm) was adopted to ensure minimal seating with a standard tightening force, while avoiding abutment screw distortion on the tightened side and framework dislodgment on the unscrewed side, where the vertical marginal discrepancy was measured [40].

Given that errors may be introduced through conventional impression methods [34], an inherent inaccuracy in the range of 50 µm, in any axis, was described by Assunção et al. [20]. In the present study, the mean vertical discrepancy (20-28 µm) was found to be within the clinically acceptable range (10-150 µm), and in agreement with previously published studies which have reported gaps ranging from 2 µm to 112 µm [27, 29]. The results showed no significant difference between polyether and polyvinyl siloxane at various angulations, therefore the null hypothesis was not rejected. In other words, implant divergence (0, 10, 20, or 30 degrees) did not affect the accuracy of definitive casts fabricated from nonsplint open tray impression technique.

These results are in agreement with several studies reporting no difference between the two impression materials for partially edentulous situations [20, 31, 32]. However, Yilmaz et al [33] and Vojdani et al. [18] reported no difference between PE and VPS in parallel implants, whereas VPS was more accurate in angulated two-implant and four implant casts respectively. On the other hand, Sorrentino et al. [10] reported a higher accuracy for VPS in non-parallel implants, whereas PE yielded the best results with parallel implants using an experimental cast with four implants.

Considering implant angulation, previous studies found that angulation up to 15 degrees had no effect on impression accuracy in partially edentulous arches with two or three implants [9, 22, 23, 25, 27, 28]. At 20 degrees, contradictory results were reported with one study [35] showing accurate impression with angulated implants and another study [27] showing impression inaccuracy. Furthermore, other studies have shown that the more non axially inclined the implant, the greater the inaccuracy of the impression and resultant implant definitive casts [18-21, 24, 31]. In fact, numerous studies targeting internal or external connections in a two-implant cast reported that increasing the implants divergence or convergence angle (greater than 20 degrees) negatively affected the impression accuracy [19, 21, 24, 31]. At 25 degrees, Rutkunas et al. [31] and Filho et al. [24] reported that the direct splinted technique was more accurate. Whereas, Assuncao et al. reported conflicting results with one study showing greater accuracy with the direct splinted technique [21] and another study showing more accurate results with the direct non-splinted [19]. However, when implant angulation was equal or greater than 30 degrees, Lin et al. [34] stated that the amount of divergence between the two implants did not affect the accuracy of definitive stone casts created through traditional open tray impressions. Whereas, Lee et al. [29] and Howell et al. [26] reported that the open-tray technique was more accurate than closed-tray in a 3 and 4 implant casts respectively.

These conflicting results, among the abovementioned studies, may be partially attributed to different study designs, different numbers of implants, different implant angulations, different prosthetic connection mechanisms, and different methodologies to assess accuracy.

Owing to the use of non-hex UCLA abutments, rotational and horizontal errors could not be detected in the present study. However, the lack of measurements comprising the whole interface of the abutment/implant assembly might be a limitation. Moreover, the results of the present investigation are limited to two external connection implants and may not be relevant for impressions that have higher or lower numbers of implants. Additionally, when interpreting the results regarding the accuracy of implant impressions, machining tolerance should have been taken into consideration. Further limitation that makes extrapolation of the data to the clinical situation difficult is the absence of saliva, blood, sulcular fluid which may affect the accuracy of the impressions.

Future in-vivo studies should be conducted with different numbers of implants, different implant systems, angulations, depths, connection geometry and other impression materials.

Conclusion

Within the limitations of the present in-vitro study, the following conclusions can be drawn:

-The misfit values were not significant among groups. Therefore, for external connection implants, impression accuracy is not affected by neither impression material (polyether and addition VPS) nor implant angulation (0, 10, 20 and 30 degrees) in partially edentulous situations simulating a two-implant scenario.

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