Evaluation of alternative approaches in designing CAD/CAM frameworks for fixed partial dentures

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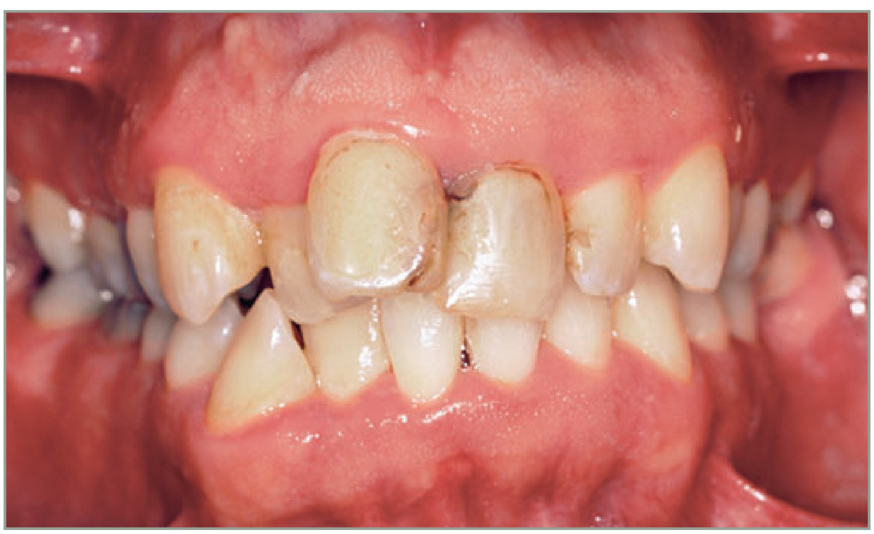

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Abstract

Background: The need for proper framework support for the veneer porcelain in fixed partial dentures (FPDs) has been well documented. The aim of this study was to compare the variations of the support provided by frameworks designed directly on the computer, or indirectly through scanning a wax pattern.

Materials and Methods: For each of the six upper anterior FPDs that were involved in the study, prior to milling one framework was designed conventionally in wax and scanned and another one was directly digitally designed. The restorations consisted of full coverage retainers and pontics on natural abutment teeth and implant abutments at random. The produced frameworks were evaluated regarding the incisal support they would provide to the veneer material, as this was revealed by a silicon key representing the outer labial contour of the provisional restoration. The distances between the distal and mesial incisal-edges and the corresponding negative incisal contour of the key were measured with a digital caliper. Statistical analysis was performed by linear regression with the design method, abutment type and pontic type as independent parameters (a = 0.05).

Results: The values recorded were: means ± SD: 3.3 ± (direct CAD), 2.6 ± mm (indirect CAD) 2.7 ± mm (for retainers on natural teeth) 2.7 (on implant abutments), and 3.3 mm (for pontics). Linear regression analysis showed that the indirect technique provided more intimate incisal support for the ceramic veneer on a statistically significant level and even more so in the pontic areas.

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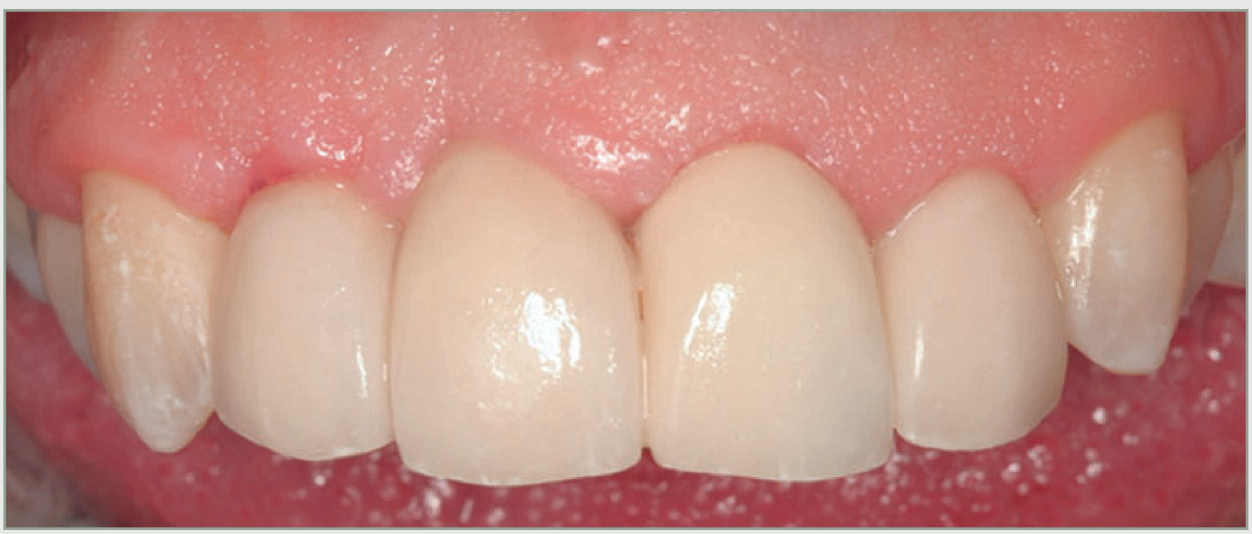

Introduction

Digital technology provides supporting frameworks for metal-ceramic and all-ceramic veneered fixed partial dentures (FPDs), through CAD/CAM techniques.[1-3] Although digital intraoral scanning is also presently aiming to establish the new era in impression making,[4] a conventional impression is still mostly used to produce a working model with removable dies. The digital model of the supporting framework (CAD) is either designed conventionally with wax and scanned in a second stage or directly digitally on the computer.[5] Either way the scanned framework is then digitally manufactured by milling (CAM) in metal (Ti, Cr/Co & others) or ceramic material (Alumina, Zirconia).

Well-documented traditional framework design principles[6-8] should certainly be applied when metal frameworks are digitally produced. The uneven thickness of the veneer porcelain, generating shrinkage differences during firing, inevitably induces internal stress that causes cracks and fractures. Therefore, the metal framework design should be directly related to the shape of the final prosthesis to provide sufficient support and even thickness of the veneering porcelain in the metal-ceramic restoration.

These principles – well established decades ago for metal-ceramic restorations – are reappearing in the dental literature that concerns all-ceramic FPDs. Increasing scientific evidence presently is showing that appropriate veneering porcelain and supporting core thicknesses may decrease internal stress, reduce mechanical failure, and optimize esthetics in Alumina or Zirconia supported ceramic restorations.[9-11] The customization of milled ceramic frameworks has been introduced to provide even and controlled porcelain thickness to prevent adhesive and cohesive fractures of the veneer porcelain.

In order to provide this support in the anterior restorations, the framework in the abutment crown areas should not simply cover the natural or the implant abutments by a minimum thickness incisally or occlusally, but it should be designed according to the three-dimensional anatomy of the final restoration. Moreover in the pontic areas, the full curve of the dental arch of the final restoration should also receive the necessary three-dimensional support provided by its proper orientation and design.

Currently, there is a trend within industrial and laboratory dental technology groups claiming that digital design can effectively substitute all armamentarium and techniques involved in the design that are produced conventionally by wax on an articulator.

The aim of the present investigation was to comparatively examine the incisal anterior support provided by CAD/CAM frameworks for both retainer and pontic units of FPDs in the upper anterior region, produced randomly by the two previously mentioned design methods. The null hypothesis was that both methods equally provided the necessary support.

Materials and methods

Selection of subjects

The present investigation was designed on a basis of case series in order to at-

Table 1 List of the restorations placed per material, abutment and pontic type (All-Cer: All-ceramic, Met-Cer: Metal-ceramic for the corresponding teeth)

Patients' restorations	Tooth abutments	Implant abutments	Pontics
1. (All-Cer)(A)		13, 11, 21, 24	12, 22, 23
2. (Met-Cer)	14, 11, 21, 23		13,12, 22
3. (All-Cer)	12, 21		11
4. (Met-Cer)		11, 22	21
5. (All-Cer)		13, 11, 21, 24	12, 22, 23
6. (All-Cer)	13	12, 22, 23	11, 21
Total	7	13	13

tain indicative documentation regarding the design differences prior to milling (CAD). The actual material (metal or zirconia) used in milling (CAM) was not considered relevant. Yet the diversity regarding the natural tooth and implant abutments was taken under consideration in the evaluation.

The supporting frameworks that were tested were fabricated within the process of restoring the upper anterior region, between the first premolars, of six patients by four all-ceramic and two metal-ceramic fixed partial dentures. The restorations involved full coverage retainers and pontics at random. In two of the patients the restorations were to be cemented on natural abutment teeth, in three others on implant abutments and in one the restorations involved both natural and implant abutments (Table 1). A total of 33 framework units on 7 natural abutment teeth, 13 implant abutments and 13 pontics were tested.

Clinical preparation

Acrylic provisional restorations successfully fulfilling the patients' functional, phonetic and esthetic requirements were fitted on the prepared natural abutment teeth or the custom implant abutments (Figs 1 to 4). Precision final impressions (Permadyne, 3M ESPE) of the abutments were produced by polyether impression material. Alginate impressions of the dental arches, including the fitted provisional prostheses and the opposing arches, along with segmental anterior intraoral registration records (Ramitec, 3M ESPE) in maximum intercuspation as guided by the posterior teeth, were also produced. The registration material was strictly confined in the area of the abutments.

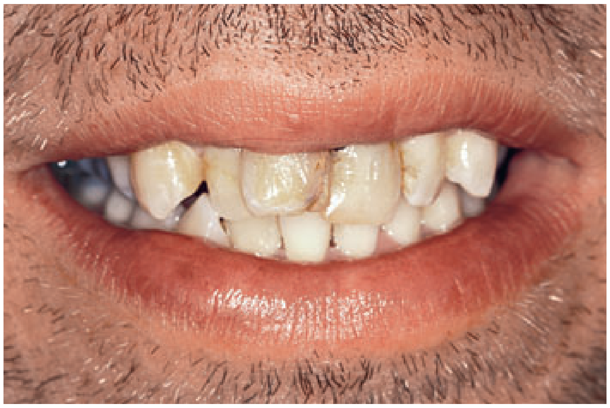

Fig 1 Preoperative extraoral condition of patient number 3.

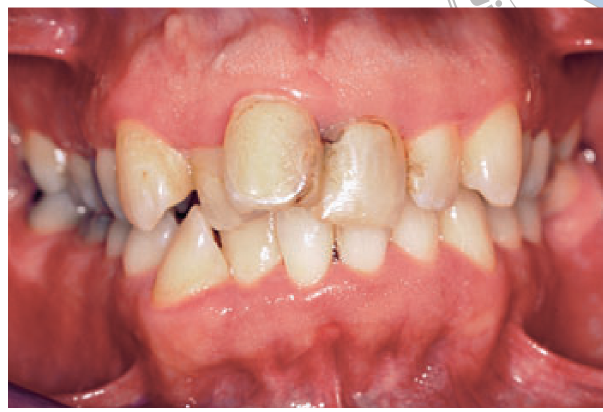

Fig 2 Preoperative intraoral condition of patient number 3.

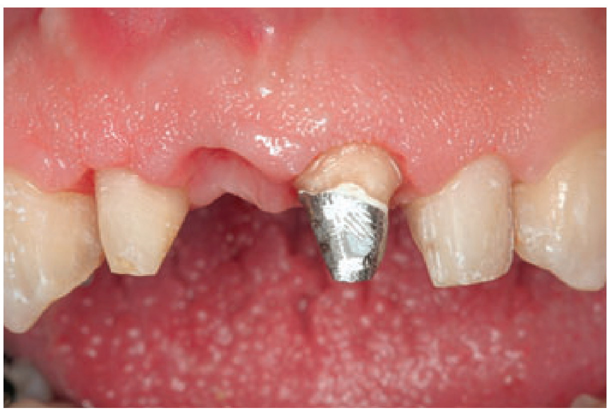

Fig 3 Teeth 12 and 21 were prepared for full coverage FPD after crown-lengthening 12, the extraction of 11 and guided tissue healing of the socket. 22 was prepared for a porcelain laminate veneer.

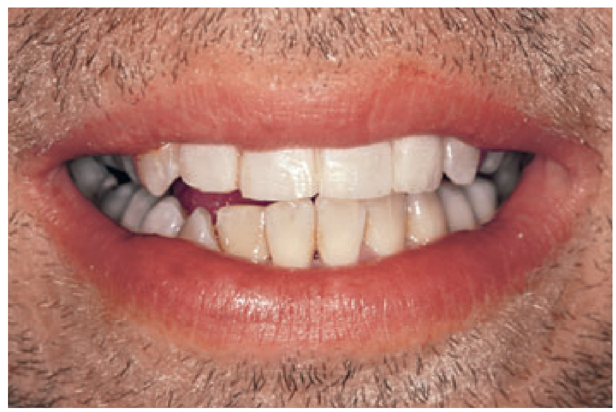

Fig 4 Acrylic provisional restorations fulfilling the patient's functional, phonetic and esthetic requirements.

Laboratory preparation

The models deriving from the above impressions were forwarded to the laboratory to be mounted on an articulator. Labial condensation-silicone keys (Coltene Rapid, Coltene Whaledent) were used to register the incisal curve of the transitional prostheses and their relationship with the opposing arches.

CAD/CAM procedures

For all six cases, two frameworks were produced. Two different ways were followed individually by two dental technicians (DT I and DT II,) to produce blindly the digital data (CAD) for the milling procedures (CAM). This was done digitally directly on the computer (Group I) and conventionally with wax on the articulator that was scanned to produce the digital outer form of the framework (Group II).

Group I

The mounted models and the labial silicone keys of the transitional prostheses related to the opposing lower arches were scanned by the CAD software (I-mes, Wieland) and the frameworks were digitally designed. This procedure depended on the three-dimensional digital design judgment of the DT I. The design was based on the information provided strictly from the computer software regarding the interocclusal relationships as determined by the scanned mounted models. Preexisting digitally stored elements in the CAD software such as pontics or connectors were accordingly applied (Fig 5).

Group II

Wax patterns of the frameworks were conventionally constructed by DT II on the articulator, guided by the labial silicone keys and were then scanned by DT I (Fig 7). Thus, the digital design of the frameworks strictly depended on the design conventionally produced in wax on the working models.

Measurement procedures

Assuming that the silicone labial key of the provisional restoration efficiently represented the required outer labial form of the completed veneered FPD, the measured distances of the milled frameworks would represent the future veneer thickness. The incisal support provided to the veneer by the framework was thus evaluated considered as being the most crucial. The milled frameworks

Fig 5 Digitally designed framework based on elements in the CAD software (pontics and connectors) and the interocclusal relationship as determined by the scanned mounted models (Method I).

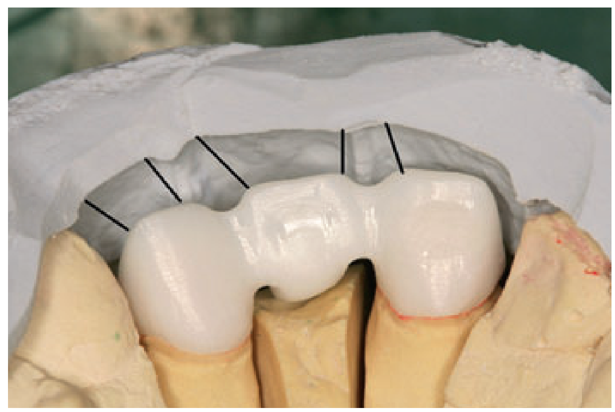

Fig 6 Zirconia framework produced by digital direct design projected on the working cast bearing the labial silicone key (Method I).

Fig 7 Wax framework supporting the outline contour of the provisional restoration as projected by the labial silicone key (Method II).

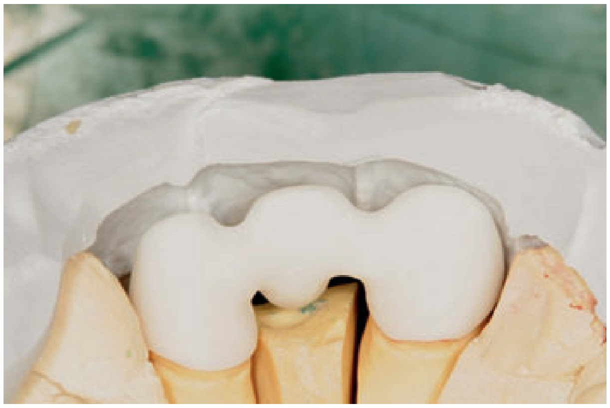

Fig 8 Zirconia framework produced by indirect digital design projected on the working cast bearing the labial silicone key (Method II).

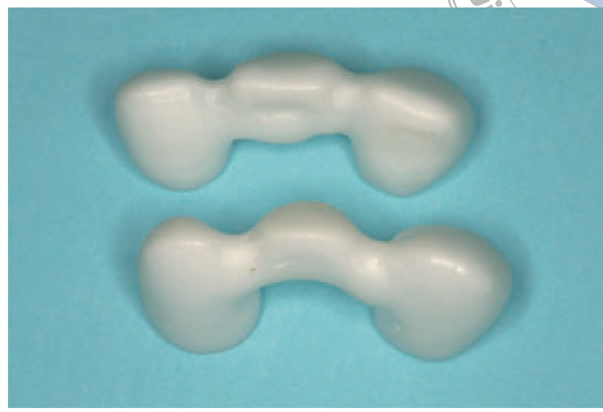

Fig 9 Zirconia frameworks produced by Method I (top) and Method II (bottom).

were positioned on the working models bearing the labial silicone keys deriving from the transitional prostheses applied intraorally (Figs 6 and 8). The distances between the incisal edges from the corresponding sites of the negative incisal contour of the future veneered restoration, as demonstrated by the silicone keys, were measured with a digital caliper accurate to ± 0.01 mm. For the incisors, two measurements were made orienting from the distal and mesial corners of the framework towards the corresponding incisal corners of the projected veneered restoration (Fig 6). For the canines, one measurement was made to the tip of the cusp and for premolars to the tip of the labial cusp. The measurements were indicative of the future veneer thickness and of the relevant support provided by the frameworks, thus not representing absolute values produced by a standardized procedure, but rather a judgment means of a clinically relevant procedure.

Statistical methods

The statistical significance of the differences of the mean values was evaluated by linear regression analysis. The independent parameters tested were the fabrication method (direct CAD vs indirect CAD), the abutment type (tooth vs implant abutment and tooth vs implant pontic). The dependent variable was the distance of the framework from the corresponding surface of the silicone key. A 95% confidence level was chosen for statistically significant differences (a = 0.05).

Results

The mean values and standard deviations of the distances measured (in mm) in relation to the fabrication method and abutment and pontic types are presented in Tables 2 and 3. The results of the linear regression analysis are summa-

Table 2 Results of distance per fabrication method

Fabrication method	N	Distance (mm) Mean ± SD
Direct CAD	55	3.3 ± 0.7
Indirect CAD	44	2.6 ± 0.5

Table 3 Results of distance per abutment type

Abutment type	N	Distance (mm) Mean ± SD*
Tooth abutment	16	2.7 ± 1.1 a
Implant abutment	42	2.8 ± 0.5 a
Tooth pontic	9	3.6 ± 0.6 b
Implant pontic	32	3.3 ± 0.5 b

* Same letters a and b indicate mean values with no statistically significant differences (P > 0.05)

Table 4 Results of linear regression analysis for the groups tested

Distance (mm)	Coef	Standard Error	t	R>[t]	[95% Conf Interval]	
Direct vs indirect CAD	-0.73	0.11	-6.72	0.000	-0.95	-0.51
Tooth vs implant abutment	0.12	0.17	0.68	0.50	-0.22	0.46
Implant abutment vs pontic	0.70	0.18	3.94	0.000	0.35	1.05
Tooth abutment vs pontic	0.82	0.22	3.73	0.000	0.38	1.26
Cons	2.94	0.13	21.50	0.000	2.67	3.21

rized in Table 4. The results showed that the fabrication method (direct CAD vs Indirect CAM) and the abutment type were statistically significant predictors of the distance. Pairwise analysis in the abutment type showed that there were no statistically significant differences between tooth versus implant abutments and between tooth and implant pontics. The main statistically significant difference was between abutments and pontics. For all six patients, the frameworks fabricated by the indirect CAD method were chosen and used to finalize the restorations (Figs 9 to 12).Thus the null hypothesis was rejected.

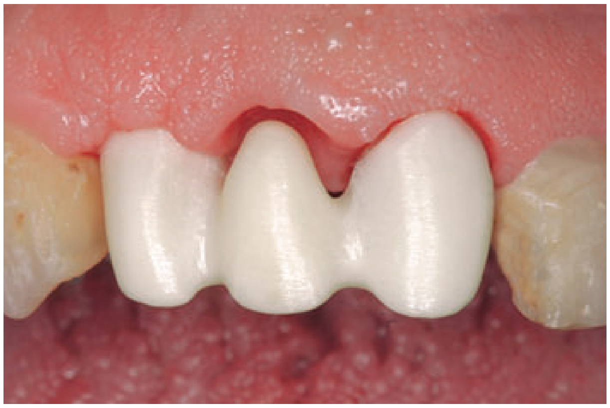

Fig 10 Preferred framework try-in.

Fig 11 Final restorations immediately after cementation.

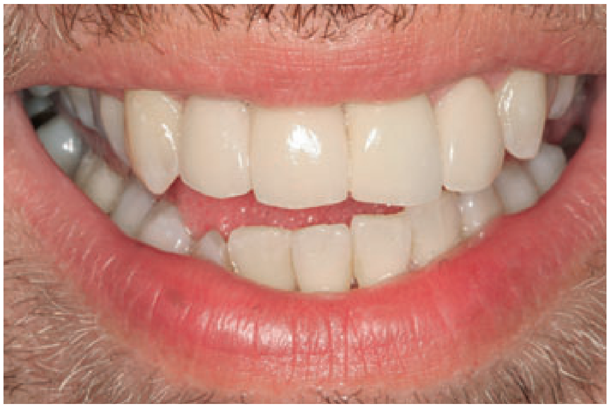

Fig 12 Extraoral clinical condition of patient number 3.

Discussion

Well-documented, traditional framework design principles should certainly be applied when metal frameworks are digitally produced for metal-ceramic FPD's.[6,7] The uneven thickness of the veneer porcelain, generating shrinkage differences during firing, inevitably induces internal stresses that cause cracks and fractures.[8] Therefore, the metal framework design should be entirely based on the shape of the final prosthesis to provide sufficient support and even thickness of the veneer porcelain of the metal-ceramic complex.

These principles, established decades ago for metal ceramic restorations, are reappearing in the dental literature concerning all-ceramic FPDs.[9] Increasing scientific evidence is presently showing that appropriate porcelain and core thickness may decrease internal stress, reduce mechanical failure, and optimize esthetics in alumina or zirconia-supported ceramic restorations.[10,11] One of the most commonly seen problems in the zirconia-supported restorations is the chipping or cracking of the layering ceramics.[12] This insufficiency of the veneering material can be attributed to several reasons, such as insufficient mechanical properties, unfavorable tensile stresses between the zirconia frameworks and the veneer material that develop during firing/cooling, and finally the inappropriate framework support.[13-15] Customization of milled ceramic frameworks and dual scanning has been introduced to provide even and controlled porcelain thickness to prevent adhesive and cohesive fractures of the veneer porcelain.[9]

In this investigation, a blind comparative examination of the incisal-anterior support provided by CAD/CAM frameworks was accomplished. The constructed frameworks of the FPDs in the upper anterior region produced by scanning of the conventional waxed replica were shown to provide better control in adequately supporting the veneer porcelain of the final restoration. In all measured points the conventionally designed frameworks presented significantly smaller distances from the corresponding negative contour of the future veneered restoration, as demonstrated by the silicone labial keys that derived from the transitional prostheses. The areas of the bridgework with the largest deviations from the ideal were the pontic areas.

A number of speculated reasons could possibly explain the above-mentioned finding. The labial silicon key, representing the negative profile of the final restoration as produced by the transitional prosthesis, provides extra assistance during conventional waxing in properly orienting the 3-dimensional framework design. Working on actual models mounted on an articulator offers a comprehensive representation of the full dental arches, which is superior to the digitally provided information. The digitally designed pontic elements were found to be even more inadequate, possibly due to the fact that the lack of anatomic landmarks for the technician to follow was more prominent at the edentulous areas. Finally, the use of previously stored digital designs for the development of the pontic substructure elements creates an extra barrier against accurate customization.

As an alternative to direct, digitally designed pontic elements, a cast derived from the provisional restorations can be scanned and the final framework can be digitally designed via a "cut-back" approach.

Conclusions

Considering the technology used in the present investigation and its application (hardware, software and human intervention) the following conclusions can be drawn:

- Supporting frameworks fabricated through CAD/CAM fully designed on the working model with wax and then double scanned prior to manufacturing are more likely to efficiently support the future veneer than the ones directly designed on the computer.
- The above conclusion is even more valid when the FPD under contraction involves pontic units.

Acknowledgement

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