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Review

Is the Number of Appointments for Complete Denture Fabrication Reduced with CAD-CAM? A Literature Review

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Abstract: One of the key arguments in favor of digitally produced complete dentures (CDs) is the requirement for less patient visits in comparison to the conventional workflow. However, it is not yet clear if this argument is accurate; nor, if indeed the insertion of the complete dentures is achieved in fewer appointments, how many are required. The purpose of this literature review was to investigate the reported number of required patient visits for the production of digitally fabricated CDs. An electronic search was performed in PubMed/MEDLINE using three groups of keywords: “complete dentures”, “CAD/CAM”, and “Appointments” with their alternative forms. Out of the initial 157 results, 36 articles were automatically selected utilizing exclusion keywords. After consensus between the two examiners, eight articles were finally analyzed and presented in a table. The majority (75%) of the reports came from institutions, and the average number of appointments up to complete denture insertion was 4.1, not always including try-in dentures. In this study, it can be concluded that, with a digital workflow, the insertion appointment is reached in fewer visits than the conventional five-visit procedure which is commonly taught in dental schools.

Keywords: CAD-CAM; complete denture; digital denture; milling complete dentures; 3D printed dentures; try-in dentures; time management; post-insertion appointments; patient visits

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1. Introduction

Older patients are usually accompanied by general health issues commonly affecting their treatment plans [1,2]. Therefore, the suggested dental treatment plans should be realistic, straightforward and versatile, aiming to restore the lost functionality of the stomatognathic system and to fulfill the esthetic needs of the patient. There is no doubt that Complete Dentures (CDs) still remains a realistic and affordable treatment approach for edentulous patients [3–5]. Nevertheless, the conventional production technique with heat and pressure polymerization of PMMA is associated with dimensional changes, which affects the intaglio surface of the denture and might lead to patient discomfort and additional patient visits for adjustments [6–8]. Additionally, these changes might also affect the artificial teeth positions, deteriorating the quality of the prosthesis [9–11].

In recent years, digital technology has offered alternative and versatile workflows for CD production [12–16]. The implementation of a digital workflow for CD manufacturing is reported to be associated with advantages such as better mechanical properties of the base, improved fit with the supporting tissues, better accuracy in teeth position, reduced chair time, shortened delivery period and archiving [17–26]. However, these advantages come over time after a certain learning and improvement period. Furthermore, the leap into the new technology requires an entrepreneurial mindset and careful analysis of the investment risks, which are not always obvious [27–30].

One of the most underlined advantages of the CAD/CAM CDs is the reduced time with the patient on the dental chair, which decreases the functional costs and which is considered as an asset available for more profitable operations [19,31,32]. Additionally, the new technology promises shorter delivery periods. However, it is not yet clear if these advantages are indeed present in clinical practice and to what extent. Therefore, the objective of this literature review was to analyze the available literature on the treatment of edentulous patients with CDs produced through a digital workflow, focusing on the number of required appointments for the delivery of the complete dentures. Also examined as secondary objectives in this literature review were the inclusion of try-in dentures in the reported digital workflows and the reported number of required post-insertion appointments. The hypotheses were that the same number of appointments would be required for the insertion of CDs for both the digital and the conventional workflow, and that no difference would be found in the post-insertion appointment number either.

2. Material and Method

An electronic literature search was conducted in the PubMed database. A search strategy was applied and the criteria for the inclusion and exclusion of available scientific reports were defined. Therefore, the included articles were those that cumulatively met the following criteria: (a) clinical scientific reports of any kind; (b) articles published in English, German, Dutch or Greek language during the last decade; (c) cited in the database of the National Library of Medicine (https://pubmed.ncbi.nlm.nih.gov/ accessed on 29 November 2021) with references to digital and conventional CDs; (d) reporting the number of needed appointments and/or their duration; as well as (e) the presence of at least one word from all of the three groups outlined below. Criteria for excluding reports and articles were: (a) the language, if it was not one of the four mentioned above; (b) the presence of the terms "fixed prosthesis/es", "review", "partial", "implant", "implant-supported", "inlays", "veneers", "duplicate (-) denture/s" or "copy (-) denture/s; and (c) the absence of all words from at least one of the following three groups of terms.

The three used groups of search terms, were: (Group 1) "complete denture/s", "denture/s", "removable complete denture/s", "removable denture/s", "digital denture/s"; (Group 2) "CADCAM", "CAD-CAM", "CAD/CAM", "computer aided design & computer aided manufacturing", "digital dentistry", "milled", "milling", "3D-printed", "three-dimensional printed", "3D-printing", "three-dimensional printing"; (Group 3) "appointments", chair time", "chair-time", "delivery time", "time management", "time efficiency", "time efficient", "visit/s".

The literature research strategy in this review included one database and was based on PRISMA suggestions for systematic reviews. It included three steps: (1) initial analysis of the resulting titles, (2) initial selection of the articles that fulfill the purpose of this paper through abstract reading and (3) full text reading of the selected articles by two independent reviewers. [33] In case of opinion discrepancy, the matter was discussed until a consensus was reached, and only the articles that met the inclusion criteria were further analyzed.

3. Results

The response of the initial search was 157 articles, from which 123 were excluded, because they did not meet the inclusion criteria. From the excluded articles, 94 were irrelevant, 7 were in an unknown language and 22 had an older publication date than the last decade. This first sweep was conducted automatically by the application of search filters and identification of exclusion terms in the advanced search interface of PubMed. After an initial screening from both scholars, 24 additional articles were excluded, including seven reviews or surveys [12,19,34–38], seven describing workflows that required preexisting dentures [39–45], one not referring to digital workflows in clinical practice [46], four analyzing material properties [47–50] and five laboratory studies [51–55]. Next, 10 articles were eligible for full text analysis, of which one was excluded because of insufficient classification between CDs and overdentures [56], and one because it was a technique presentation accompanied with clinical pictures without any presentation of the cases [57]).

Finally, eight studies were shortlisted for analysis after the consensus of the two reviewers [58–65] (Figure 1).

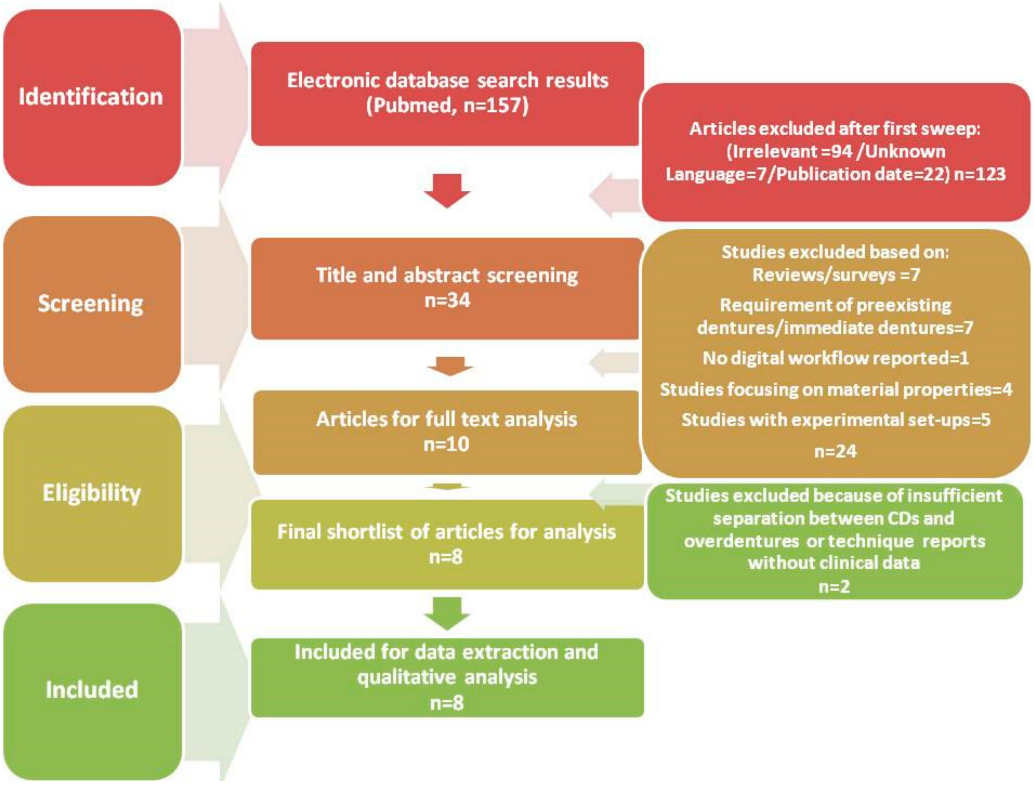

Figure 1. PRISMA flow diagram showing the identification, screening, eligibility and inclusion process of the studies (n: number).

The remaining eight articles were further analyzed, and specific information was collected pertaining the study design, number of treated patients, required number of appointments for the delivery of digitally processed CDs, inclusion of try-in or wax dentures, utilized computer assisted system and details about post-insertion patient visits. Additionally, the establishment in which the clinical trial took place was noted (Table 1).

Table 1. Studies reporting treatments with Complete Denture implementing digital workflows.

	Report	Study Design	Patients	Visits	Try-In	Follow-Up †	System	Est. ‡
1.	Schlenz MA et al. (2019) [58]	Retrospective Pilot Study	10	4.6 ± 0.7	yes	IP 1.7 ± 0.05, FP 2.07 ± 0.32	DD, IV	In
2.	Smith PB et al. (2020) [59]	Retrospective case analysis	30	4	yes	n/a	DD, IV	In
3.	Kim TH et al. (2021) [60]	Retrospective clinical study	636	5	yes	2 (in most cases)	DDB and teeth resins	In
4.	John AV et al. (2019) [61]	Case series	15	2	no	2	BDS	PP
5.	Drago C et al. (2019) [62]	Retrospective clinical Study	106	4	yes	1.7	ADC; GDS	PP
6.	Clark WA et al. (2021) [63]	Retrospective, cross-sectional clinical study	314	4.1 (2–6) *	yes	1.6 (0–3) *	ADS	In

Table 1. *Cont.*

	Report	Study Design	Patients	Visits	Try-In	Follow-Up †	System	Est. ‡
7.	Schwindling FS et al. (2016) [64]	Pilot clinical trial	5	5.4 (4–6) *	yes	n/a	IBCZ; WD	In
8.	Millet C (2018) [65]	Case Report	1	4	yes	IP 2 (7, 45 d), FP 3 (6, 12, 24 m)	IBCZ; WD//SR; IVD	In

* range. † IP: Initial Period. FP: Functional Period. n/a: Not Available data. d: days. m: months. DD, IV: Digital Denture, Ivoclar Vivadent. DDB: Dentca Denture Base II, Dentca Inc. BDS: Baltic Denture System (Merz Dental GmbH). ADC, GDS: AvaDent CORE; Global Dental Sciences. ADS: AvaDent–System; Global Dental Sciences. IBCZ, WD: IvoBase CAD for Zenotec; Wieland Dental. SR, IVD: SR Vivodent SPE; Ivoclar Vivadent Dental. ‡ Est: Establishment, In: Institution, PP: Private Practice.

From the analysis of the data provided in the remaining studies, the mean number of appointments needed for the denture delivery was 4.1 appointments. In seven out of eight studies (87.5%) an evaluation appointment for a try-in denture was included. The mean number of the required post-insertion appointments was 2.7 appointments, and two out of eight studies did not report any data regarding this aspect.

4. Discussion

In this review, even if a try-in denture was always evaluated, the mean required number of appointments for the insertion of CDs seems to be shorter with the digital workflow than with the traditional five-visit one, which is taught in dental schools (preliminary impressions, final impression, maxilla-mandibular records, wax denture try-in, final denture insertion) [59]. Hence, in this study, the initial hypothesis that there would be no difference between the digital and the conventional workflow regarding the number of patient visits appears to be erroneous.

CAD/CAM dentures have been introduced by advertising their advantages over conventional ones, with reduced chair time and number of visits being the main factors considered. In this literature review, it was revealed that the mean number of appointments needed for the denture delivery was slightly over four appointments. In this literature review the vast majority of studies incorporated a try-in denture in the reported digital workflow. Notwithstanding, if, in the entirety of cases, a try-in denture was to be evaluated in-situ, an additional appointment would be needed, thus increasing the mean number of appointments to 4.26, which is roughly four appointments per case. This result is in accordance to a recently published case report by Villias A et al. (2021) [14]. In that case report an upper complete denture was inserted in the fourth appointment, and the patient only came back for one post-insertion appointment without complaining for any additional problems later over the phone.

Regarding this finding, an experienced dentist, could narrow down the required appointments to four, following a simplified conventional workflow, without compromising the quality of the final prosthesis (impression, records, wax denture try-in and wash impression and finally insertion). On the contrary, it should also be taken into account that dental schools might select workflow combinations with more appointments for educational purposes, thus downgrading the potential benefit of the new technology regarding a lesser number of patient visits. In this analysis, the vast majority (6/8) 75% of the clinical trials were conducted in institutions, namely dental schools. In those reports the patients received their CDs after 4.5 visits, on average. Only two of the reports concerned private practices. In those reports the patient left with a CD after two and four visits, respectively. However, in the shorter workflow no try-in denture was inserted.

Digital workflows that reach the denture insertion appointment after only one visit require experience and careful case-selection [35,61]. The digital transformation, however, is not necessarily associated with fewer appointments for every case, as this literature review suggested (See Table 1, rows 1, 3, 6, 7) [58,60,63,64]. It is not clear or self-evident that the incorporation of digital technology is immediately leading to faster production per case, unless it is stated otherwise by the system's protocol [35,58,61].

In this review the analyzed studies have explained their protocol regarding digital CDs. Schlenz MA et al. (2019) [58] followed the four-visit protocol, which is analytically described by Schwindling FS et al. (2016) [64]. According to the described procedure, in the first visit, the initial impressions were taken, the occlusal plane was determined and the initial registration of the maxillomandibular relation was recorded. In the second visit, a functional impression was taken, the occlusal plane was determined, and the anterior esthetics were determined as well as the definitive registration records. In the third visit, the trial dentures were evaluated, and, in the final visit, the CDs were inserted. In their study, Schlenz MA et al. (2019) [58] also categorized the reasons for which, in some cases, additional appointments were needed. They summarized the causes for additional appointments to faults concerning the midline, tooth size, horizontal and vertical overlap of the denture teeth and the occlusal vertical dimension.

Deak A et al. (2015) [57] presented a digital technique which included a two-visit protocol. In the first visit, the appropriate prefabricated thermoplastic tray was selected and modified, an impression was taken, including peripheral seal, the vertical and horizontal dimension and the occlusal level were defined and, finally, the lip was appropriately supported. In the second visit, the insertion of the CDs took place according to the traditional procedures. In their description, the authors mention that a try-in, wax denture was not clinically assessed. In order to spare clinical time, this step only took place virtually. However, they underline the need for a try-in denture to be clinically evaluated in difficult cases, adding at least one appointment in the described procedure.

Smith PB et al. (2020) [59] also described a four-visit protocol. In the first visit, initial impressions were taken with products provided by the Ivoclar Vivadent dental company, including the AccuGel impression material, AccuGel stock trays and armamentarium for the papillameter reading and centric bite relationship records. In the second visit, the final impressions were taken, including border molding procedures. The maxillomandibular records were also included in the second visit, utilizing 3D bite plates and gothic arch tracings. In the third visit, a CAM trial denture was tried. The fourth visit the final prosthesis was inserted. The authors mention that additional appointments might be necessary at the try-in of the CAD denture in order to perform corrections regarding the teeth or the occlusion, including remanding of the casts. However, they report that, with appropriate instructions, minor corrections could be performed directly by the technician before milling the final denture.

Kim TH et al. (2021) [60] followed a step-by-step procedure. In the initial visit, the preliminary impressions were taken, and next, the final impressions with custom trays. In the third appointment, jaw relations and the necessary information for denture teeth selection was recorded utilizing wax rims. In the fourth visit, adjustments regarding fit and aesthetics were made utilizing printed dentures, and, in the final fifth visit, the definitive printed dentures were inserted. The authors do not report reasons for additional appointments up to the insertion one, nevertheless they include in their analysis the number of remakes, which suggests the repetition of the whole process from the first appointment.

John AV et al. (2019) [61] followed the two-visit protocol for a complete denture fabrication utilizing the armamentarium provided by the Baltic Denture System (Merz Dental GmbH, Lütjenburg, Germany). In the first appointment, the occlusal vertical dimension was measured utilizing conventional techniques, trays were selected and modified and final impressions were taken. The occlusal plane was determined, and information regarding the anterior teeth was collected. Finally, the maxillomandibular relations were recorded and verification photographs were taken. In the second patient visit, the dentures were inserted and minor adjustments took place. The authors do not mention any deviations on the two-visit protocol, although they underline the need for the application of the method in cases with a favorable maxillomandibular relationship. Additionally, they do not mention if preexisting dentures were utilized to initially note the occlusal vertical relationship, which was verified in following the steps of the first patient visit.

Drago C et al. (2019) [62] described a four-visit protocol for CD fabrication. In the first patient visit, initial impressions were taken. In the second visit, definitive impressions, jaw relation records and wax rim adjustments for tooth selection were performed. In the third appointment, a try-in denture was evaluated and adjustments were made if necessary. In the fourth visit, the definitive denture was inserted. The authors did not report any reasons for additional patient visits up to the insertion appointment.

Clark WA et al. (2021) [63] reported a four-step procedure for digital denture production. In the first patient appointment, preliminary impressions were taken, and, in the second appointment, the definitive impressions. In the third appointment, a try-in denture was evaluated and aesthetics of the anterior teeth were adjusted. In the final appointment, the definitive dentures were inserted. The authors provide a chart showing that the digital workflow might require up to six visits for the insertion of the new dentures. Additionally, there were cases where a remake was necessary.

Schwindling FS et al. (2016) [64] implemented a four-visit protocol. In the first visit, preliminary impressions were taken and preliminary jaw relationships records were obtained. In the second visit, definitive impressions were taken, the occlusal plane was reevaluated and information about maxillary anterior teeth was gathered. The vertical dimension was evaluated utilizing gothic arch tracings. In the third patient visit, acrylic trial dentures were evaluated and adjustments were made, if necessary. The adjustments were reevaluated, increasing the total number of appointments before the definitive dentures were inserted in the final session.

Millet C (2018) [65] followed a five-visit procedure. In the first visit, preliminary impressions were made and preliminary records of the jaw relations were made. In the second appointment, final impressions were taken, the occlusal plane was evaluated and the occlusal vertical dimension was determined. The centric relation was recorded utilizing a gothic arch, and information for the selection of the upper anterior denture teeth was collected. In the third patient visit, a trial denture was inserted. In the fourth visit, adjustments were made on the trial denture. In the fifth visit, the definitive complete dentures were inserted. Although the author mentions the implementation of a four-visit procedure, the need to let the patient use the try-in denture added a visit to the procedure.

With the aid of digital technology, fast and reliable treatments could be provided for frail older patients who might suffer from motor dysfunction and cognitive impairment, especially when duplicate dentures are produced [2]. On this direction, Saponaro PC et al. (2016) found that digitally manufactured CDs are reported to require a reasonable number of post insertion visits, ranging from none, for some cases, to more than three visits, with a mean of 2.08 visits [56]. Other authors report an average of 3.3 post-insertion visits for adjustments [15]. The conducted analysis of the literature in this study revealed a mean of 2.7 post-insertion appointments; however, only six out of eight studies reported the number of follow-up visits. Additionally, the fact that the majority of reports come from dental schools might imply that more than the necessary appointments might have been included in a workflow because of educational purposes. Therefore, even less post-insertion appointments might be required [14]. In this study, the reported post-insertion appointments in private practices were less than two [61,62].

Since the success of the treatment of a patient with CDs depends on the clinician's experience, the effectiveness of the collaboration between the clinic and the dental laboratory and the patient's attitude towards the suggested treatment, there is not a widely accepted fixed number of required post-insertion appointments for the functional acceptance of complete dentures. Regarding conventionally produced CDs, an average of four post-insertion appointments for adjustments for the upper complete denture and six appointments for the lower complete denture seem to be reasonable estimations [5,8].

In this study, taking into account the aforementioned number of post insertion appointments regarding the conventional workflow, the hypothesis that there would be no difference in the number of post-insertion patient visits seems to be faulty.

Regarding this finding, the reported number of post-insertion appointments might also be affected by the educational prerequisites defined by the curricula of the dental schools. For instance, in the dental school of Athens, Greece, at least two post-insertion appointments are required before a predoctoral student completes a treatment with CDs.

One reason for the relatively small number of post-insertion appointments with digital workflows might be attributed to the characteristics of the CDs because of the new technology. A relevant analysis in a recent systematic review, despite the limited data, indicated that digitally produced CDs achieve better retention than conventional ones [17]. This can be explained by clinical and in-vitro studies, in which digitally produced complete dentures show a similar or better fit of the intaglio surfaces [20,22,23,25,26].

It is also known that the more retentive and stable the prosthesis and, subsequently, the fit of the denture, the easier and faster the adaptation is for the patient. The fit, in turn, depends on dimensional stability throughout the construction. It is known that acrylic resin, which is the material of choice for conventional denture manufacturing, is subject to dimensional changes due to polymerization shrinkage. These changes are three-dimensional, linear and volumetric. These continue to take place after the insertion and are assisted by water absorption (swelling) and the gradual breaking of double bonds [6,7].

Dimensional changes of the acrylic base affect fit and are also combined with alterations in teeth positions. Tooth movement also occurs during flasking and processing stages of the pack-and-press denture fabrication technique, thus affecting the accuracy of the occlusal contacts. Additionally, even a minimal denture tooth movement can have a significant effect on the vertical dimension of the occlusion [9–11]. As a consequence, warpage of the base, when combined with tooth movements, cause a complex phenomenon of overall denture inaccuracy. Regarding teeth positions and occlusion by means of accuracy and reproducibility, it seems that digital CDs exhibit less tooth movement compared with the conventional methods of construction [24]. Fewer visits after placement of digital CDs are adequately justified with the combination of a better fit and a better and stable occlusion in the delivered CD.

The reported post-insertion visits, however, might include several scheduled appointments. However, the unscheduled ones are of practical importance for the practitioner. Drago C et al. (2019) did not find any differences between digitally manufactured CDs and conventionally ones, regarding post-insertion visits [62].

Although the literature is still lacking long-term, randomized clinical trials that are crucial for the wide acceptance of the new technology, it has attracted the attention of many researchers worldwide [16]. Peroz S et al. (2021) did not find any significant differences in the overall scores of the German version of the OHIP questionnaire, from a pool of 16 participants who were treated with new complete dentures produced either with a five-visit conventional workflow or with a two-visit digital one [45]. In that study, however, regarding the post-insertion follow-up, conventional dentures were associated with less functional limitations after two weeks, and the patients felt less handicapped three months post-insertion. Digital dentures were associated with more physical pain after the first two weeks post-insertion [45]. The Baltic Denture System was selected in that study, which requires careful case selection and follows a specific processing.

It is known that, in the initial period, patients receiving dentures require adjustments [5]. Arakawa I et al. (2021) compared conventionally and digitally produced dentures and could not find significant differences between the groups [30]. The evaluated adjustments that took place post-delivery included the treatment of areas of excessive pressure, denture relining or repairs [30].

Kim TH et al. (2021) did not find any significant differences regarding post-insertion adjustments, repairs or remakes between conventional and 3D printed CDs [60]. On the contrary, they did find that discomfort and pain or detectable ulcer lesions were significantly higher with conventional CDs rather than digital ones.

Regarding the risk of bias in the utilized studies, the relevant analysis showed that five out of the eight resulting studies (62.5%) were sponsored, supported with materials or were declared to have conflicts of interest with the commercial companies from which materials and systems were used [55,57,59,61,64]. Out of the eight studies that were analyzed in this literature review, only in three of them (37.5%) there no conflicts of interest [62,63,65].

Although interesting results have been found in this literature review, there are inherent restrictions, such as the fact that only one database was used as a source for article references. Additionally, there was no step in which the literature was freely explored. Despite the fact that an analysis of the conflicts of interest was conducted which indicated potential bias in the utilized studies, the risk of the bias was not assessed according to the PRISMA guidelines in the included studies, posing an additional limitation.

As with so many scientific breakthroughs in the past, the rise of the digital era is also associated with enthusiasm. Nonetheless, the wide application of this new technology and its potential value in everyday dentistry are slowly revealing over time. It would be interesting to see, in the future, reports about the clinical performance of the CAD/CAM removable prostheses highlighting common technical and biological complications in comparison to the conventional technique. For the time being, it seems that the production of CDs with a digital workflow concerning both clinical and laboratory procedures is applicable, with predictable results.

5. Conclusions

Within the limitations of this literature review, it can be concluded that the introduction of a digital workflow reduces the required visits up to the delivery of the CDs by at least one in comparison with the five-visit, conventional workflow commonly taught in dental schools. Additionally, in this review, digital workflows do not always include an appointment for a try-in denture evaluation. Finally, and taking into consideration the limitations of this study, we concluded that more than two follow-up appointments are required after the insertion of digitally produced complete dentures.

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