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# Error Migration in the Full-Arch Digital Workflow: Clinical Comparison of Three Implant Position Capture Protocols in a Periodontally Compromised Patient A Case Report

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***Abstract***

***Background:*** *Immediate-load full-arch implant rehabilitation depends on the accurate transfer of implant positions from the mouth to the laboratory. Every digital capture method carries its own error pattern, and that error travels through design, manufacturing and delivery until it reaches the final prosthesis. This report compares three capture protocols in the same patient and describes how their combined data were used to reach a passive definitive restoration.*

***Case presentation:*** *A 47-year-old male heavy smoker with advanced periodontitis, marked tooth mobility, subgingival caries and severely compromised periodontal support received six implants per arch through prosthetically driven guided surgery with immediate loading. Implant positions were captured with three protocols: intraoral scanning combined with photogrammetry, Medicalfit 1 (intraoral scan of scan bodies with CBCT-based correction of STL deviation) and Medicalfit 2 (splinted pick-up with a custom tray). Chairside time, handling difficulty, learning curve and outcome were recorded. Interim prostheses were delivered within 24 hours and definitive monolithic zirconia prostheses were screwed directly onto multi-unit abutments without titanium bases after finite element analysis.*

***Results:*** *Photogrammetry was the most technique-sensitive protocol in this patient. Cross-checking the three datasets with the laboratory allowed the deviations of each protocol to be identified and compensated, and the transition from interim to definitive prostheses was completed with passive fit. Soft tissues and marginal bone were stable at the one-year follow-up.*

***Conclusion:*** *No single capture protocol is perfect. Predictability depends on knowing how error migrates in each workflow and controlling it through prosthetically driven planning, guided surgery and close cooperation with the dental laboratory.*

**Keywords:** Full-Arch Rehabilitation, Digital Workflow, Intraoral Photogrammetry, Implant Impression Accuracy, Passive Fit, Guided Implant Surgery.

## Introduction

Fixed full-arch implant rehabilitation is a well-established treatment for patients with a terminal dentition. Survival rates are high, yet long-term success is measured by more than implant survival. Mechanical complications (screw loosening, fracture of the framework or veneering material) and biological complications, peri-implant mucositis and peri-implantitis above all, remain frequent and costly to manage [1, 2]. Prosthetic design is increasingly recognised as a factor that can predispose to or precipitate peri-implant disease. Over-contoured emergence pro-

files, convex prosthetic surfaces and designs that prevent effective hygiene have been linked to a higher risk of disease [3, 4]. The three-dimensional position of the implant determines which emergence profile the restoration can have [5]. A sufficient buccal bone wall [6] and an adequate band of keratinised mucosa [7, 8] also support peri-implant stability. For these reasons, implant position should be dictated by the planned prosthesis and not the reverse.

The second critical variable is accuracy. A full-arch prosthesis should be passive when screwed onto its abutments. Misfit transfers stress to screws, components and bone, and it can compromise the stability of the peri-implant tissues. Conventional splinted impressions remain a reference, but digital workflows are now standard. Intraoral scanning of complete edentulous arches is limited by the lack of fixed reference points, which causes stitching errors that accumulate across the arch [9]. Several strategies have been proposed to overcome this: auxiliary devices that add reference geometry [10, 11], merging intraoral scans with cone-beam computed tomography (CBCT) data [12] and intraoral photogrammetry [13, 14].

Each strategy introduces its own type of error, originating in the scan bodies, the stitching algorithm, the radiological data or the splinting material. That error does not stay at the capture stage. It migrates to the digital model, the design, the milled or printed prosthesis and finally to the implant-prosthesis interface. In this report the phenomenon is called error migration.

The aim of this case report is to compare three digital protocols for implant position capture in the same patient, looking at the whole clinical workflow (chairside time, difficulty, learning curve and outcome) rather than the final result only, and to show how the laboratory used the combined data to move from an immediate interim prosthesis to a passive definitive restoration.

## Materials and Methods

### Patient

A 47-year-old male presented with a terminal dentition in both arches (Figure 1). He was a heavy smoker and a former drug user. Clinical and radiographic examination showed advanced periodontitis with severely compromised periodontal support, generalised tooth mobility and multiple subgingival carious lesions. Advanced generalized periodontitis (Stage III), a history of heavy tobacco use, and multiple teeth with extensive subgingival and furcation caries. Several posterior teeth were considered non-restorable, with insufficient periodontal support and an unfavourable long-term prognosis despite potential endodontic treatment. The patient also presented with one maxillary and one mandibular implant, both showing >70% radiographic bone loss. Considering the overall periodontal and restorative prognosis, extraction of the remaining teeth and full-arch implant rehabilitation was considered the most predictable treatment option. The treatment plan agreed with the patient was the extraction of all remaining teeth and fixed full-arch rehabilitation supported by six implants per arch, with immediate loading. The patient gave written informed consent for treatment and for the publication of his clinical data and images.

### Diagnosis and prosthetically driven planning

Three datasets were acquired: extraoral and intraoral photographs, intraoral scans of both arches (STL) and a CBCT scan (DICOM) (Figure 2). The photographs were used to define the new smile and tooth position. The prosthetic set-up was designed first and then merged with the STL and DICOM files in the planning software R2GATE, MEGAGEN.

Implant positions were planned from the final prosthesis. For each site, depth, angulation and mesiodistal position were chosen to allow a correct prosthetic emergence while keeping room for the biological width of the soft tissues and a sufficient buccal bone wall. Six implants were planned in the maxilla and six in the mandible.

**Upper Jaw**

- **Brand and Model:** All implants are MegaGen brand, AnyRidge model.
- **Tooth #11:** Diameter 4.0 mm, length 13.0 mm.
- **Tooth #13:** Diameter 4.5 mm, length 15.0 mm.
- **Tooth #15:** Diameter 4.5 mm, length 10.0 mm.
- **Tooth #21:** Diameter 4.0 mm, length 13.0 mm.
- **Tooth #24:** Diameter 4.0 mm, length 13.0 mm.
- **Tooth #26:** Diameter 4.0 mm, length 10.0 mm.

**Lower Jaw**

- **Brand and Model:** All implants are MegaGen brand, AnyRidge model.
- **Tooth #32:** Diameter 3.5 mm, length 13.0 mm.
- **Tooth #35:** Diameter 4.0 mm, length 11.5 mm.
- **Tooth #36:** Diameter 4.5 mm, length 11.5 mm.
- **Tooth #42:** Diameter 3.5 mm, length 13.0 mm.
- **Tooth #45:** Diameter 4.0 mm, length 11.5 mm.
- **Tooth #46:** Diameter 4.5 mm, length 10.0 mm.

### Surgical Phase

Surgical guides were produced from the plan (Figure 3). Extractions, implant placement and multi-unit abutment connection were completed under guided surgery in a single session. A graft consisting of Bio-Oss® (deproteinized bovine bone mineral; Geistlich Pharma AG, Wolhusen, Switzerland), autologous bone, and autologous plasma was prepared and mixed to form a sticky bone graft. The graft was used to fill the extraction sockets for alveolar ridge preservation.

All implants achieved an insertion torque of 40–50 Ncm, except for the implant placed at site 26. Due to the lower primary stability achieved at this site, immediate loading was not performed on implant 26.

### Implant Position Capture: Three Protocols

Immediately after surgery, implant positions were captured with three protocols (Figure 4).

**Protocol A:** Intraoral Scanning + Photogrammetry. The arch and soft tissue were captured with an intraoral scanner, and implant positions were recorded with an intraoral photogrammetry system using photogrammetry scan bodies connected to the multi-unit abutmentsusing shining 3D model. Both datasets were then aligned to build the working model. In this case the gingiva had to be scanned from one side only before the photogrammetry step.

**Protocol B:** Medical fit 1. Scan bodies MFTS7-IF were scanned intraorally. The resulting STL was then corrected in the labo-

ratory using the implant positions obtained from the CBCT, to compensate for the cumulative stitching deviation of the intraoral scan.

**Protocol C:** Medical fit 2. A custom tray designed from the plan was used to pick up the transfer components, which were splinted to the tray with Structur. The resulting implant positions were used by the laboratory to correct the deviation of the STL dataset.

For each protocol the following were recorded: time to screw and unscrew components, ease or difficulty of the procedure, learning curve for the clinical team and the resulting digital model. The protocols were compared with the conventional splinted pick-up principle and with the in vitro accuracy data available in the literature [15].

### Interim Prostheses

Screw-retained interim prostheses were delivered within 24 hours (Figure 5). The design did not use titanium bases: a modified base was seated directly on the multi-unit abutment with a longer prosthetic screw, and the prostheses were milled in polymethyl methacrylate (PMMA) with a flexural strength of approximately 100-115 MPa Huge PMMA. PMMA is a validated provisional material for immediate-load complete-arch prostheses in fully digital workflows [16]. The intaglio surface followed the S.E.A.L. concept (Socket Extension Alveolar Lock), in which the prosthesis extends into the extraction sockets to support the soft tissue during healing.

### Finite Element Analysis and Definitive Prostheses

Before manufacturing the definitive restorations, the laboratory ran a finite element analysis (FEA) of the multi-unit base design to compare stress distribution with and without a titanium base (Figure 9). The definitive prostheses were designed in monolithic zirconia, screwed directly onto the multi-unit abutments without titanium bases, and milled on a five-axis machine.

### Follow-up

The patient was reviewed at 24 hours, 10 days, 3 months and 1 year. Evaluation included intraoral photographs, panoramic radiographs and soft tissue assessment.

## Results

### Comparison of Capture Protocols

Table 1 summarises the clinical behaviour of the three protocols. Protocol A (intraoral scanning + photogrammetry) was the most complex in this case. The need to scan the gingiva from one side only and then perform the photogrammetry step made it more sensitive and technically demanding.

**Table 1:** Clinical comparison of the three implant position capture protocols

| Criterion | A. Intraoral scanning + photogrammetry | B. Medicalfit 1 | C. Medicalfit 2 |
|---|---|---|---|
| Time to screw and unscrew components | [4min ] | [3 min] | [10min ] |
| Handling difficulty | Medium | Easy | High |
| Learning curve | Steep | Easy | Difficult |
| Main error source | Soft tissue capture from one side and alignment with photogrammetry | Intraoral scan stitching, corrected with CBCT | Splinting material and tray seating |

### Laboratory Analysis and Passivity

Working with the three datasets, the laboratory identified the deviations introduced by each protocol and used them to establish the final implant positions. The interim prostheses fitted passively and remained in function without fracture during healing. The definitive zirconia prostheses were seated passively at the first try-in .

Finite element analysis demonstrated the feasibility of the prosthesis, both for the connection without titanium bases and from a structural point of view, in PMMA for interim use and in ZrO2 for definitive use. FEA of the definitive prostheses showed stress concentrated around the screw access channels, with the highest values in the distal areas (Figure 9).

### Clinical Follow-up

At 24 hours the patient left with a fixed functional and aesthetic restoration (Figure 6). At 10 days soft tissue healing was uneventful. At 3 months the peri-implant mucosa showed healthy contours shaped by the interim prostheses (Figure 7). The definitive restorations were delivered (Figure 8) and at one year the panoramic radiograph showed around all twelve implants, with no mechanical or biological complications (Figure 10).

## Discussion

This case shows that the question in full-arch digital workflows is not which protocol is perfect, but how error migrates in each one and how it can be controlled. Every method in this comparison introduced error from a different source. Photogrammetry measures the relative position of the scan bodies with high precision, but it depends on a separate soft tissue scan and on the alignment of both datasets [13].

In this patient, with fresh extraction sockets, bleeding and limited access, that step proved demanding. Correcting the intraoral scan with CBCT uses a dataset that is already available and does not depend on stitching, although it is limited by the voxel size and by artefacts around metal components [12]. A splinted pick-up with a custom tray restores a physical connection between the implants, which is the principle behind conventional splinted impressions, but it adds the dimensional behaviour of the splinting material and the seating of the tray as new sources of error.

Comparing the three datasets in the same patient turned these errors into information. When protocols disagreed, the laboratory could identify which step had introduced the deviation and correct it before manufacturing the definitive prostheses. This cross-checking is only possible with close cooperation between

the clinician and the dental technician. The laboratory is not only a manufacturer; it is part of the diagnostic process.

Passivity is a mechanical goal with biological consequences. A non-passive framework loads the screws and the peri-implant bone continuously. In a patient with a history of periodontitis and heavy smoking, both recognised risk indicators for peri-implantitis [1], every avoidable stress on the peri-implant tissues matters. The same logic applies to prosthetic design. identified design features that predispose to peri-implant disease [3]. Planning implant position from the final prosthesis made it possible to design emergence profiles that respect the soft tissue and to maintain the buccal bone dimension recommended in the literature [5, 6].

In our opinion, connections to transepithelial abutments (multi-unit type) should be made in the restorative material itself, without a titanium base, regardless of whether the prosthesis is made in PMMA or ZrO2. Titanium bases add a cement interface, reduce wall thickness because two materials share the same space and can debond when the fit is not passive. They also change the emergence diameter between the interim and the definitive stages. A single-material design keeps a continuous emergence profile from the interim to the definitive restoration and avoids a gap between zirconia and titanium. The trade-off is that the connection is milled rather than lathe-machined, which is less precise, and possible microleakage between zirconia and the transepithelial component has to be considered, although this interface lies away from the implant connection.

Soft tissue management was the last element. Interim prostheses that extend into the extraction sockets support the soft tissue from the first day and help shape a stable peri-implant mucosa. The presence of keratinised mucosa has been associated with better peri-implant soft tissue health in full-arch rehabilitations [7].

In the author's practice, 222 full-arch prostheses were delivered between 2017 and 2025. Of these, 207 (93 %) had no fracture and 15 fractured, with causes attributed to design errors, printing errors or unknown causes. These unpublished data support the routine use of digital protocols, but they come from a single practice and were not collected under a research protocol.

This report has limitations. It describes a single patient, so the findings cannot be generalised. The follow-up is one year. Controlled studies with quantitative trueness and precision measurements are needed to compare these protocols formally.



**Figure 1:** Initial situation. Extraoral view and intraoral frontal view showing advanced periodontitis, tooth mobility and subgingival caries.

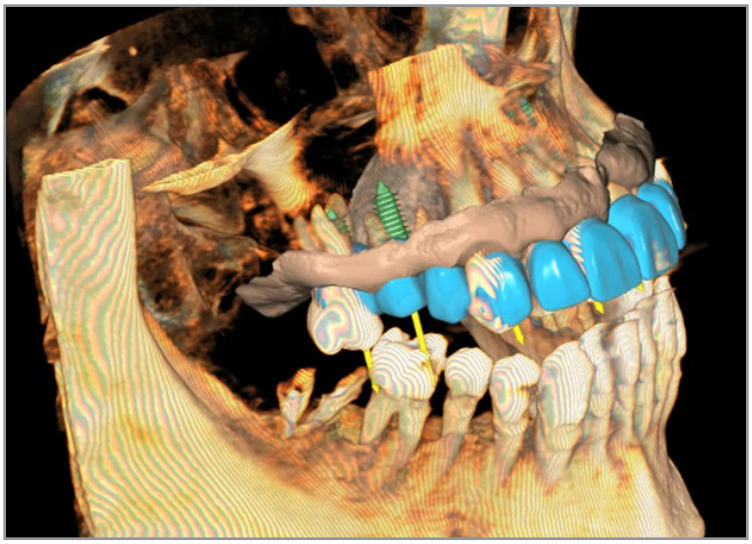


**Figure 2:** Digital diagnosis. Photographs, intraoral scan (STL) and CBCT merged with the prosthetic set-up; prosthetically driven planning of the upper and lower arches.

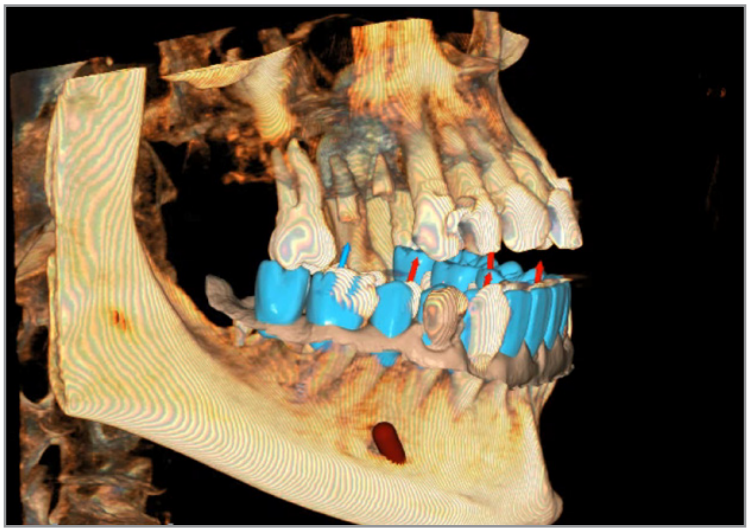


**Figure 3:** Guided surgery with the surgical guides and implant placement in the mandible.



**Figure 4:** The three capture protocols: (a) intraoral scanning combined with photogrammetry scan bodies;

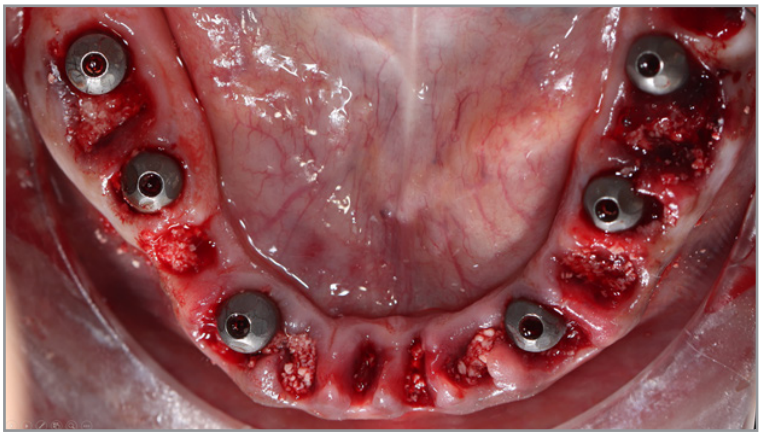


**Figure 4:** The three capture protocols: (b) Medicalfit 1, scan bodies and CBCT-based STL correction;

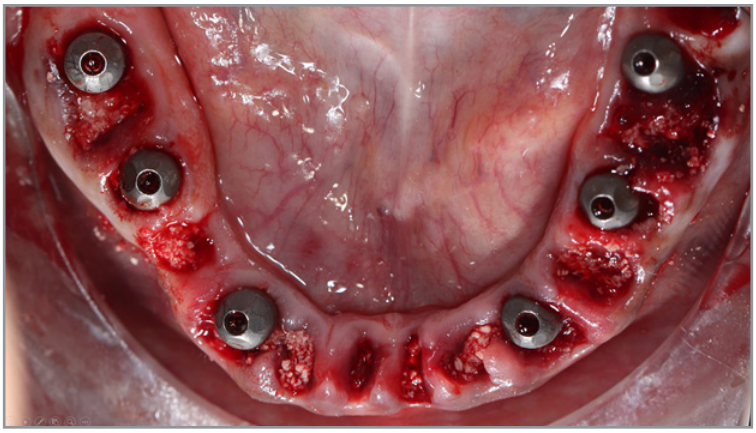


**Figure 4:** The three capture protocols: (c) Medicalfit 2, custom pick-up tray.



**Figure 5:** Interim prostheses without titanium bases and S.E.A.L. design.

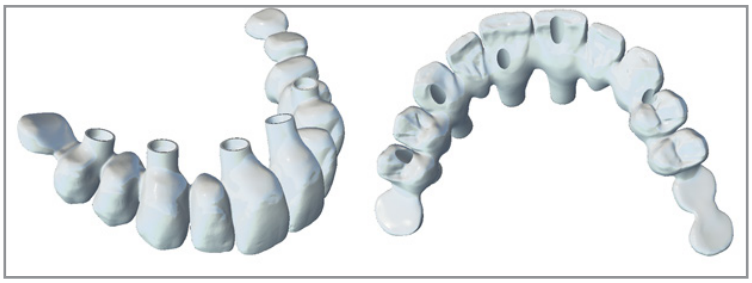


**Figure 6:** Delivery at 24 hours: intraoral view and panoramic radiograph.



**Figure 7:** Peri-implant soft tissues at 3 months.

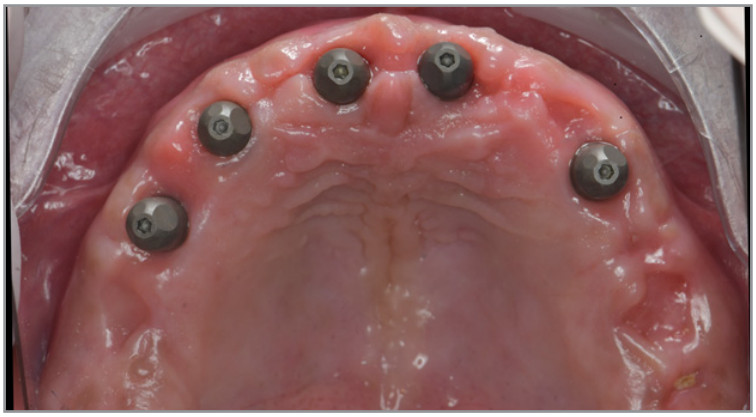


**Figure 8:** Definitive monolithic zirconia prostheses.

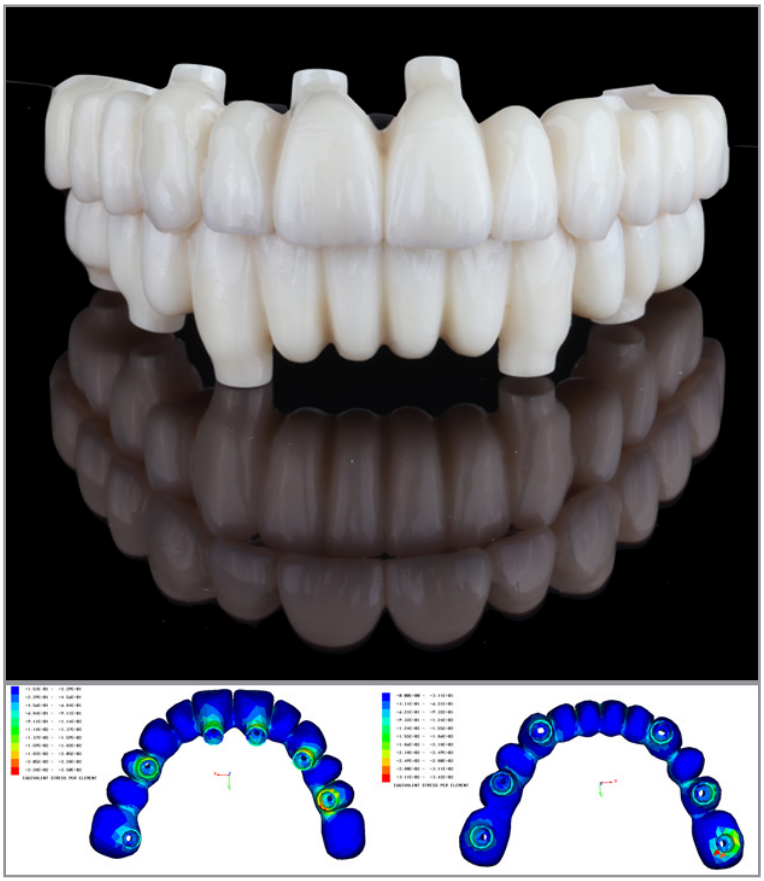


**Figure 9:** Finite element analysis of the definitive upper and lower prostheses (equivalent stress per element).



**Figure 10 A:** Final result: intraoral view, extraoral comparison before and after, and panoramic radiograph at one year.



**Figure 10 B:** Final result: intraoral view, extraoral comparison before and after, and panoramic radiograph at one year.

## Conclusion

No single capture protocol is perfect. Each digital workflow introduces its own error, and that error migrates to the final prosthesis unless it is identified and compensated. Combining diagnosis, prosthetically driven planning, guided surgery, digital capture and laboratory analysis made it possible to move from an immediate interim prosthesis to a passive definitive restoration, with the aim of long-term mechanical and biological stability and a lower risk of peri-implantitis. Digital dentistry is not the use of a particular technology; it is understanding the strengths, limits and error migration of each protocol and integrating them into a predictable workflow.

## Declarations

### Informed Consent

Written informed consent was obtained from the patient for treatment and for the publication of this report and its accompanying images.


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## Data Availability

The data supporting this report are available from the corresponding author on reasonable request.

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