Minimally invasive prosthetic procedures (MIPPs) have been suggested and utilized for the esthetic rehabilitation of severely worn dentition. Minimizing the reduction of tooth structure and the use of additional adhesive techniques are key elements to ensure long-term results. This article presents the long-term result of this restorative technique. A total of 1,040 lithium disilicate restorations were adhesively luted, and 45 patients and 87 arches were treated. The cumulative survival rate recorded was 99.15%, with a 10-year survival probability of 96.5%. These remarkable results strongly support the use of MIPP as a restorative option for severely worn dentition.

The goal of every prosthetic treatment is to restore esthetics and function, both in single-tooth and full-mouth rehabilitations. In the latter case, the esthetic and functional parameters the clinician has to consider and improve are more complex and greater in number; moreover, the whole prosthetic treatment should be performed while respecting the principle of minimal invasiveness.

The minimally invasive prosthetic procedure (MIPP) technique suggested by Fradeani et al is a prosthetic procedure combining the restoration of esthetics and function, being as minimally invasive as possible. This technique aims to create mainly additive restorations in order to maintain as much tooth enamel as possible; by using adhesive techniques, the clinician will be able to considerably improve the longevity of the prosthetic restorations.

It is possible to divide the MIPP techniques into two categories: The first one involves cases in which the patient’s initial occlusion is maintained (confirmatory approach; MIPP0 and MIPP1); in the second category, the treated cases require an occlusal modification by repositioning the mandible (reorganization approach; MIPP2 and MIPP3). MIPP3 has four guiding principles, which are analyzed...
in this article. The principles are as follows:

1. Moderate increase of VDO to gain interocclusal clearance. The treatment should involve at least one arch.
2. Minimally invasive tooth preparation to reduce the amount of tooth being removed and preserve the maximum enamel quantity on axial and occlusal surfaces. A light chamfer finish line is used.
3. Minimal ceramic thickness (up to 0.5 to 0.8 mm) due to a monolithic lithium disilicate, which assures adequate fracture resistance without excessive removal of tooth structure. The minimum thickness will be determined by the adhesive substrate; lithium disilicate restorations have proven to be reliable if bonded on enamel in reduced thickness (0.5 to 0.8 mm). If only dentin is present, a minimum ceramic thickness of > 1 mm is recommended.
4. Adhesively bonding the restoration, preferably to enamel, is likely the key for long-term success.

Case Presentation

A 35-year-old woman presented to the first author’s clinic, expressing concerns about the esthetics of her smile. In particular, she pointed out that the lengths of her incisors were insufficient to be visible when the smile was not forced; the incisal edges were starting to wear down; and she wanted to have a brighter tooth shade (Figs 1 and 2).

A complete clinical oral and radiographic examination was per-
formed (Fig 3). Significant intraoral findings were moderate erosion in the anterior area with missing anterior guidance, as well as three missing teeth already replaced with implants.

The initial study cast was mounted at the new vertical dimension of occlusion (VDO; Fig 4) on a semi-adjustable articulator (Denar Mark II, Denar) using an arbitrary face-bow transfer and posterior wax record.

The diagnostic wax-up (Fig 5) was performed in accordance to the esthetic checklist completed with GE-TApp, a specific application developed for treatment planning to facilitate data collection, data processing, and communication with the dental laboratory.

A mock-up was created using composite resin, and the esthetics and functional parameters were evaluated (Figs 6 and 7). A calibrated tooth reduction was executed, and polyether impressions were made (Figs 8 and 9).

Lithium disilicate restorations were heat-pressed and finished by a master laboratory technician. After the required try-in clinical phases, the restorations were adhesive luted with a light-curing resin cement (Fig 10). After cementation, an ideal esthetic, biologic, and functional integration was achieved (Figs 11 to 14). Final full-mouth radiographs were taken (Fig 15).
Fig 9. The anterior preparations show the complete preservation of the original enamel of the anterior (a) maxillary and (b) mandibular teeth.

Fig 10. The tooth preparations of the (a) maxillary and (b) mandibular arches show the minimal invasiveness of the MIPP technique.

Fig 11. The prosthetic rehabilitation finalized with the MIPP technique.

Fig 12. The prosthetic rehabilitation results in an increased naturalness of the smile line and an improvement in the patient’s self-confidence.

Fig 13. The (a) right and (b) left canine guidance now show a correct disclusion of the posterior area.
Fig 14 Close-up views of the anterior (a) maxillary and (b) mandibular teeth show a pleasant appearance and an adequate biologic integration for both arches.

Fig 15 The final full-mouth radiographs show the overall integration of the restorations in the patient’s mouth.

Fig 16 Kaplan-Meier analysis of survived and complication-free teeth.
Materials and Methods

The present multicentric, prospective clinical trial involved patients considered to be ideal for inclusion in the MIPP3 technique study, as they were seeking complete rehabilitation with a planned increase of VDO for esthetic and prosthetic needs due to loss of tooth structure. Patients were enrolled and treated in three different private practices by three different operators (M.F., L.B., and R.T.). Exclusion criteria were poor oral hygiene and gingival inflammation. A total of 45 patients met inclusion criteria (29 women, 16 men; average age: 52.6 years). All patients were categorized as MIPP3. Three patients had a single arch restored, while 42 had both arches restored, for a total of 87 arches treated.

A total of 1,040 restorations were fabricated in lithium disilicate (IPS e.max Press, Ivoclar Vivadent) and adhesively luted.

Prosthetic Treatment

A systematic rehabilitative approach was followed to formulate the correct treatment plan, using a meticulous protocol to collect data on the esthetic and functional parameters. All these data were sent to the dental technicians, who followed the clinicians’ indications and provided a wax-up and a mock-up and fabricated the provisional restorations.

After evaluating the esthetic, functional, and biologic integration of the temporary restorations for a reasonable period of time, the clinicians finalized the prosthetic rehabilitations.

All restorations were performed with a traditional workflow, with polyether or polyvinyl siloxane impressions, and poured with Type IV stone master cast. Master casts were cross-mounted, and five different dental laboratories manufactured the heat-pressed restorations.

The restorations were evaluated during the oral hygiene follow-up sessions, which patients were asked to attend every 3 to 6 months. A restoration was considered to be a failure when a major complication requiring replacement occurred. Minor chippings (< 1 mm²) that only needed to be re-polished were recorded as complications. The average observation time was 50 months (range: 16 to 132 months).

Preparation Design

Posterior teeth

The preparation designs for posterior teeth are as follows: (1) Buccal occlusal veneer (BOV): complete coverage of occlusal and buccal surfaces of the tooth. Indicated to change the occlusion and improve esthetics on the buccal aspect. This design comprised 48% of posterior preparations. (2) Table top: complete coverage of the occlusal surface, which may or may not include proximal boxes. Indicated to change occlusion if no esthetic improvement is necessary. This design comprised 21% of posterior preparations. (3) Overlay/onlay: complete or partial cusp coverage with supra-gingival margin. This design comprised 7% of posterior preparations. (4) Complete crown: traditional coverage mainly used in cases of previous crowns needing replacement. This design comprised 23% of posterior preparations.

Anterior teeth

The preparation designs for anterior teeth are as follows: (1) Buccal veneer: light cervical chamfer and butt-joint incisal-edge preparations. This design comprised 46% of anterior preparations. (2) Full veneer: Minimally invasive preparation extended to the palatal area with a light cervical chamfer margin extended circumferentially at 360 degrees. This preparation design appears to be similar to a complete-coverage crown. However, on the palatal area of the upper anterior teeth, because of the space obtained by increasing the VDO, refining only the tooth preparation is usually sufficient (rather than performing a traditional grinding procedure). Following this approach, it is possible to maintain all present enamel in the palatal aspect of the anterior teeth. This design comprised 36% of anterior preparations. (3) Complete crown: a traditional coverage mainly used in cases of previous crowns needing replacement. The tooth substrate is entirely on dentin or buildup materials. This design comprised 18% of anterior preparations.

Different preparation designs were chosen based on the specific clinical scenario. Out of 1,040 restorations, 554 were performed in the posterior area (53%) and 486 in the anterior area (47%).
erior restorations were all monolithic, while all anterior restorations were layered with the exception of six laminate veneers that were monolithic. A total of 54% of restorations were monolithic, and 46% were layered.

The restorations were tried-in at a dedicated appointment, during which occlusion was adjusted and final shade matching was assured, before proceeding with the cementation appointment.

**Adhesive Cementation**

The intaglio surface of every restoration was treated with 4.5% hydrofluoric acid (Ivoclar Vivadent) for 20 seconds, then thoroughly rinsed with water. After having dried and treated the restorations with a ceramic primer (Monobond Plus, Ivoclar Vivadent), they were completely dried for 60 seconds.

The restorations were cemented with resin cements, either dual-cure cement (n = 196) or light-cure cement with an etch-and-rinse approach (n = 844). The cements were chosen based on preparation retentive properties and the thickness of the restorations. The dual-cure or light-cure cements were applied on the restorations, which were then polymerized with a lamp. All residual excess cement was removed after the cementation process.

**Statistical Analysis**

The survival and complication rates were calculated with Kaplan-Meier survival curves. Log-rank test ($P < .05$) was used to detect significant differences between groups.

**Results**

A total of nine failures were recorded in six patients during the observation time, with one patient having four ceramic bulk fractures. The average time of failure was 56.5 months (4.7 years). Cumulative survival rate was 99.15%, providing an annual failure risk of 0.2%.

Nine minor chippings were observed in five patients over an average time of 61.2 months (5.1 years). All chippings required only polishing to correct them. These minor chippings were recorded both on anterior ($n = 5$) and posterior ($n = 4$) restorations. The cumulative complication-free rate (no failure or chipping) was 98.3%, with an annual complication risk of 0.4%.

According to Kaplan-Meier estimated survival function, the probability of survival at 10 years is 96.5% (95% confidence interval [CI]: 99.7% for ULC, 93.3% for LCL), and the estimated complication-free function is 93% (95% CI: 97% for ULC, 85.8% for LCL) (Fig 16). The survival rate in men was 98.5% and 99.2% in women. The failures were recorded only in posterior teeth, with a 98.4% survival rate. Anterior teeth presented a 100% survival rate (Table 1).

Considering the different restoration types chosen for the posterior area, the least-invasive restorations exhibit a higher survival rate (BOV = 98.7%; table top = 100%; and onlay = 97.5%) compared to traditional complete-coverage crowns (96.1% (Table 2). This difference was not statistically significant ($P > .05$).

No statistically significant differences were found between each variable analyzed (sex, position, monolithic or layered, and cement type), most likely because of the limited number of failures recorded during the observation period.
Discussion

All patients treated with an MIPP3 approach were considered to be at a high risk for functional difficulties due to the significant amount of tooth structure that had already been lost.

In the last few years, prosthetic rehabilitations of worn dentition have been implemented with adhesive techniques and additive procedures, whereas in the past, a subtractive approach was often used.

Preserving tooth structure is crucial to providing long-term tooth survival. As previously demonstrated, partial-coverage restorations preserve the maximum amount of tooth structure possible, while maintaining pulp vitality, compared to traditional complete-coverage restorations.22

This result is possible because of the VDO increase. Many studies show that a moderate VDO change is possible without long-term complications (ie, difficulty with speech and on chewing, tenderness, soreness, clenching, increase in bite forces, temporomandibular joint disorder or other muscle symptoms, ceramic fractures, and chippings) from both functional and prosthetic viewpoints. Most consequential symptoms are reported to be self-limiting and generally disappear after 2 weeks.24,25

The proposed MIPP demonstrated excellent clinical performance: With an annual failure rate of only 0.2% and no endodontic complications, this technique has proven to be reliable as well as effective in maintaining pulpal health. A further advantage of this technique is the potential to reduce the minimum suggested ceramic thickness (traditionally 1.5 mm, which is still valid for traditional crowns) to 0.8 mm, possibly even 0.5 mm if bonded entirely on enamel.26

A 3-mm increase in vertical dimension in the anterior area creates, approximately, a 1.5-mm increase in the molar region.27 The reachable posterior space can be split between two arches, creating almost 0.8 mm per arch without removing any sound tooth structure.

The goal of this minimally invasive approach is to preserve enamel28 in order to improve the bond strength and mechanical characteristics of the restorations.29

Ceramic restorations have proven to be successful, both in traditional crowns (with an estimated yearly failure rate of 0.2% up to 10.4 years later30) and in partial coverage restorations.31–33 In 2019, Edelhoff et

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BOV = buccal occlusal veneer.
al34 and Liebermann et al35 evaluated the survival of 104 ceramic occlusal onlays and found no failure up to 11 years later. A limitation of the data is that the study only followed six patients.

The present clinical trial is notable due to the large number of complete rehabilitations in treated patients with worn dentition (n = 45). When evaluating this remarkably high success rate, the high-risk patient pool that was restored with the MIPP approach must be taken into consideration, suggesting that this procedure should theoretically be even safer in patients with a lower functional risk.

Conclusions

In the present perspective trial, 1,040 restorations were luted, mostly on enamel, in 45 patients with VDO increase (n = 87 arches). Nine failures were recorded, only on posterior teeth, achieving a cumulative survival rate of 99.15% and an estimated survival function of 96.5% at 10 years.

The lithium disilicate restorations done with an MIPP approach showed excellent clinical performance with both complete-coverage and minimally invasive preparation designs.

None of the variables analyzed (sex, position, monolithic or layered, and cement type) displayed any statistically significant differences.

Acknowledgments

The authors declare no conflicts of interest.

References


