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The milled surface as a precision attachment

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The treatment of a complex, partially edentulous patient using a combination of fixed and removable partial dentures and precision attachments as retentive elements has long been considered as among the most sophisticated forms of care. More recently, root-form dental implants have been used for support and retention. In these patients, most, if not all, abutment teeth require some form of restoration of tooth structure. The most common restorations are full veneer crowns with associated pontics; on their lingual and proximal surfaces the creation of milled guiding planes can serve as precision attachments to enhance the stability and retention of the removable partial denture [1–6].

The longevity data of these fixed-removable reconstructions point out their high failure and complication rates [7,8]. Öwall [8] reported on the survival of 53 fixed-removable combination treatments. Distal extension-base removable partial dentures were fabricated with rigid intracoronal slide attachments. The survival rate was 65% up to 15 years. The failures primarily involved the fixed component of the reconstruction. The major reasons associated with the failure of the fixed component included periodontal disease around abutment teeth, cement failure of endodontic posts, root fractures, and fracture of the fixed restoration.

Although full or partial veneer crowns can increase the longevity of a compromised tooth, potentially negative effects are associated with this treatment. The removal of tooth structure usually is required to provide for

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the draw of the restoration and to create adequate space for restorative materials. The amount of remaining tooth structure is extremely critical for the resistance to propagation of cracks. Tooth reduction to accommodate an intracoronal attachment and to maintain crown form obviously requires additional removal of tooth structure. The placement of extracoronal attachments often creates contours adjacent to the attachments that are difficult to keep free of plaque. These contours may alter the emergence profile of the crown as well, resulting in compromised periodontal tissues. Because of these complications it would seem advisable to limit the use of precision attachments if other viable treatment options exist and if esthetics will not be compromised.

Guide planes and minor connectors

Parallel guide planes on the proximal and lingual surfaces of abutment teeth or pontics can have a significant effect on the stability and retention of a removable partial denture, as might be expected with the use of precision attachments (Fig. 1). A precision attachment is a premade device consisting of a patrix and a matrix that are machined with parallel walls with close tolerances and without taper that join an abutment and the partial denture it supports. Attachments may have, in addition, some internal mechanism to offer direct retention against removal in the path created by their machined surfaces. Their greatest contribution to retention and stability results from the precise limits they place upon the path of insertion and removal of the partial denture. If the partial denture can separate from the abutment teeth only along this very restricted path, then any dislodging forces directed at any other path will be resisted by the parallelism of the surfaces. Semi-precision attachments are generally considered to be less precise, allowing greater movements of the removable partial denture while remaining esthetically acceptable. As an alternative, parallel surfaces can be created by subtractive mouth preparation of natural teeth, through additive mouth

Fig. 1. Initial metal milling of lingual surfaces with parallel-sided milling bur.

preparation using bonded composites or metal contours, and, most commonly, in the contouring of crowns and pontics through a laboratory process generally referred to as milling [9–13].

Through careful mouth preparation and the construction of milled surfaces that are truly parallel, multiple guiding surfaces also restrict the path of removal of the partial denture. The partial denture that uses milled surfaces is also depends on the laboratory to create a casting with minor connectors that actually contact these surfaces [14]. This partial denture requires only minimal clasping to provide adequate retention. These clasps can be restricted to the posterior part of the mouth or to the lingual surfaces of the abutments; in neither case are they visible to the patient.

Sequence of therapy

To maintain control over the establishment of the milled surfaces, it is necessary to sequence the preparation of the abutment teeth. Abutments that have no need for full-coverage restorations must be the first to undergo subtractive mouth preparation to establish the path of insertion and the guide planes that can be established on axial surfaces without compromising the remaining tooth structure. Once these surfaces have been made parallel to the chosen path of insertion and removal, additive restorations, either bonded surfaces or milled crowns, are made to conform to that path (Fig. 2). To reverse this order would require the extremely difficult subtractive mouth preparation of creating parallel surfaces in enamel that are truly parallel to the additive surfaces, usually milled in metal.

Diagnostic preparation

To create ideal milled surfaces, the process must begin with a diagnostic waxing of all surfaces to be milled and a provisional setup of the teeth to be

Fig. 2. Combination of milled composite and metal lingual surfaces.

replaced. The principle is to establish a road map of the desired ideal treatment and to work out any problems in design before any clinical mouth preparation is begun [15]. A diagnostic cast, complete with all usable soft tissue contours, is placed upon the dental surveyor for an evaluation of tooth and soft tissue contours relative to a chosen path of insertion/removal. In selecting the path, which normally is parallel with the long axis of the abutments, special attention is given to identifying those proximal surfaces where parallel guide planes can be created in enamel through conventional subtractive mouth preparation.

When available contour is insufficient, additive procedures are required to create the milled surfaces. The selection of abutments favors more rather than fewer abutments to share the loads that will be placed upon the teeth [16]. Rests are selected, major and minor connectors are outlined, and retention for resin and teeth is determined. Finally, clasps and other retentive devices are planned. The diagnostic cast is duplicated in stone for later use.

Diagnostic subtractive mouth preparation for enamel surfaces is always the first consideration and is performed on the stone teeth of the diagnostic cast using the same burs or stones that would be used in the mouth. Additive composite or metal surfaces are created in wax to be parallel to those enamel surfaces previously prepared (Fig. 3). Crowns are best waxed to ideal contours, both axially and in the desired occlusal relationship with the opposing arch. They are then dusted with a talcum powder, the diagnostic cast is placed back on the survey table at the established path, and the height of contour is marked in the powder on all surfaces that might be milled (Fig. 4). The potential milled surfaces can now be evaluated, and the mouth preparation can be planned. As a general rule, the milled areas on the proximal surfaces will be as long as possible vertically, because the longer the partial casting–crown interface, the greater the retention and stability of the partial denture. Shorter guide planes are used where movement of the partial denture in function is anticipated, especially for the class I mandibular situation.

Fig. 3. Proximal rest and milled guide plane in bondable nickel-chrome alloy.

Fig. 4. Full-contour waxing of abutment restorations with height of contour marked in talc. Ready for initial wax milling.

The breadth of the milled surface depends on the size of the proximal or lingual surface of the abutment tooth. Again, the greater the surface area involved in the milling process, the greater the potential for frictional retention of the casting. A rough milling is done in the wax using the blade that is one of the components of the dental surveyor. The diagnostic cast then indicates to the laboratory the extent of the milling and the cutback of the veneer, should there be one.

The milled axial surfaces must be combined with a positive vertical stop, normally in the form of a classic occlusal or cingulum rest. When esthetics is a major consideration and the placement of a rest on the occlusal surface of a veneered crown is unacceptable, the stop is created at the gingival extension of the milled surface. The ledge created may require some compromise in the contour of the crown above the gingival marginal tissue or a greater-than-normal reduction of the axial wall of the tooth. The width of the ledge can be kept to 1.25 mm and still provide a positive rest relationship (Fig. 5). The slope of the rest seat is made acute by deepening the inner aspect of the ledge so that the tooth/frame relationship is positive, and migration of the tooth from the partial denture is prohibited.

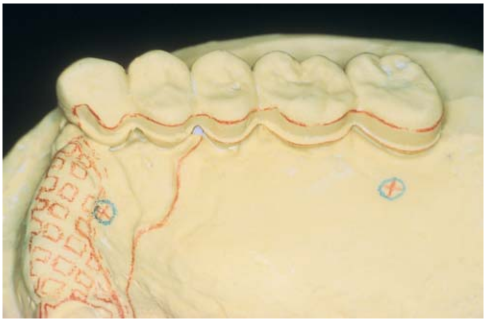

Fig. 5. Design cast showing the relationship of lingual milling and the gingival occlusal seats.

Preparation guides for milled surfaces in enamel

When a number of enamel surfaces are to undergo subtractive mouth preparation to create parallel guide planes, the problem of maintaining absolute control over the dental handpiece can be formidable. Even with the prepared diagnostic cast available as a guide to the desired parallelism, moving from one side of the arch to the other without changing the angle of the bur to the teeth is a challenge. Preparation guides made on the diagnostic cast can simplify the process and allow the clinician to treat each tooth individually.

Guide planes set to the path of insertion are first cut on the diagnostic cast, preferably with the cast mounted in a milling machine or in a shop drill press so that the planes are truly parallel to each other. The stone abutment teeth are then coated with a separating agent, and a resin coping is formed by adding a fast-setting autopolymerizing resin to the guide plane area and the occlusal surface (any hard silicone putty can be used in place of the resin.) When set, the resin is removed, and the area of the prepared guide plane is filled in with a pencil of a color that contrasts with the color of the resin. The resin is then trimmed on the milling machine or drill press until the resin over the actual guide plane becomes very thin, when the contrasting color can just be seen through the resin (Fig. 6). Any remaining resin is removed with a sharp blade, and the resin adjacent to the guide plane is blackened with a permanent marking ink. The completed preparation guide can be placed upon the unprepared tooth in the mouth. The amount and angle of the required subtractive mouth preparation is obvious because the tooth structure to be removed projects out through the window created in the guide (Fig. 7).

Clinical mouth preparation

Using the diagnostic cast or the resin template as a guide, parallel surfaces in enamel are created using nontapered diamond burs. The milled

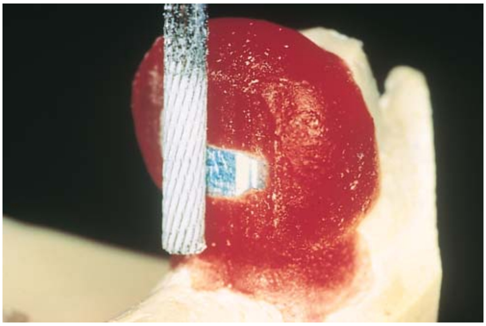

Fig. 6. Preparation coping milled to expose desired guide plane surface.

surface of the template makes aligning the diamond bur a simple matter, and the blackened surface clearly indicates when the ideal contour has been achieved. It is possible to create parallel surfaces using tapered burs, but their use requires subtle hand movements to realign the tapered bur for each abutment and makes the paralleling more difficult. Once all subtractive preparation is completed, a check cast must be made to evaluate the mouth preparation. A fast-set alginate impression poured in fast-set stone produces a usable cast in only a few moments. This cast is returned to the dental surveyor, and the parallelism of the prepared surfaces is reviewed. After any corrections are made, the prepared surfaces are polished as for any mouth preparation.

Where insufficient tooth structure is available for ideal guide plane contours and extensions, composite restorative material may be bonded onto the guide plane surfaces to increase their bulk [17,18]. The type of composite used does not seem to affect the length of service of the restoration. Isolation and careful treatment of the etched enamel are more

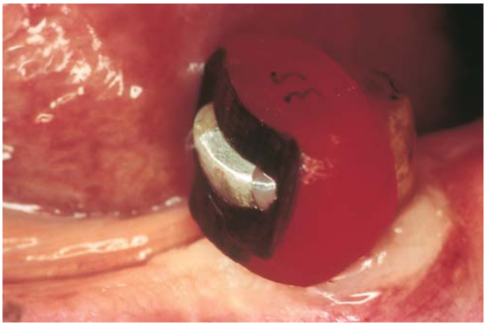

Fig. 7. Coping placed upon abutment before subtractive mouth preparation for parallel guide planes.

critical to long-term success. Resin in excess of the desired guide plane contour is then removed along with any excessive enamel contours.

Composite template for additive mouth preparation

For the few situations when multiple composite surfaces must be created, a template can be made from the diagnostic cast to aid in the placement of the composite [19]. The completed diagnostic cast is duplicated in alginate and poured in dental stone. A thin vacuum-formed clear matrix is formed on this cast to include all abutment contours to be bonded. The matrix is trimmed to extend just beyond the proposed composite addition so that the rubber dam used for isolation will not interfere with its seating (Fig. 8). The teeth to be bonded are isolated, and their surfaces are prepared. Composite is then placed in the matrix, and the matrix is firmly seated on the teeth. Light curing is completed through the clear matrix in a normal fashion. The result of using the matrix is by no means ideal and requires additional composite or subtractive modification of composite to complete all contours. Obviously, the addition of the composite material must be done before the check cast is made and evaluated.

If bonded metal guide surfaces are to be made, the abutments that will receive them must also be prepared [20]. For each restoration, at least one small groove or ledge must be created in the enamel that will be covered by the metal. These surfaces serve as positioning points to assure that the metal addition will be exactly seated for cementation with composite. The bonded metal surfaces are, by their very nature, small and difficult to position correctly without this preparation.

Fig. 8. Clear template trimmed to eliminate interference with rubber dam before placing composite. A positive lingual rest and milled proximal guide plane will be placed on this mandibular canine.

Impressions for bonded metal surfaces

Bonded metal surfaces to be milled are to be cast in a nickel-chrome alloy that can be etched, either electrochemically or with acid. The casts on which these surfaces are waxed are made of refractory investment because the small size of the surfaces makes conventional separation from a standard die and subsequent investment impractical. An impression material compatible with the refractory material must be used to make the working cast. Alginate is not compatible with phosphate-bonded investments, so a silicone or polyether material is normally used. Refractory material is notoriously weak until it is fired; therefore a custom resin tray that can be softened by a torch should be used for the final impression. After the refractory material is set, the tray can be heated and carefully peeled away from the refractory cast without fracture. A second master cast in dental stone is required for the actual milling and finishing of the metal guide plane and requires a second impression taken at the same time.

Construction of bonded metal surfaces

The refractory cast is placed upon the survey table and related to the intended path of insertion/removal dictated by the clinical mouth preparation of axial surfaces on natural teeth. If no natural guide planes exist, the path is established parallel to the long axes of the remaining abutment teeth. The only exception might be found in the class IV maxillary partial denture where the path of insertion may be influenced by undercuts in the anterior edentulous ridge.

Wax is then added to the refractory cast in excess to create the desired form of rests and guide planes. The excess wax is removed with either a blade in the surveyor or with a wax-milling bur in the milling machine, leaving one or more parallel surfaces. A plastic bristle from a toothbrush is added to one corner of the waxed contour to serve as a handle for the casting during milling and polishing of the metal (Fig. 9). This thin handle is removed once the casting has been bonded to place, and the spot is polished. The waxed guide plane is sprued as a crown would be, and the refractory cast is cut with a die saw so that only the investment associated with the guide plane is invested. Multiple guide planes can be added to a central sprue lead for casting.

Once cast and cleaned of investment, the casting is taken to the master cast and attached in its precise position using cyanoacrylate adhesive. The master cast is placed upon the dental surveyor and repositioned to the previously determined path of insertion/removal for the actual milling procedure. Nontapered milling burs are used to refine the guide planes on the metal surfaces. Clinical evidence does not indicate the degree of final polish that should be placed on the metal, but the surface that results from a standard milling bur is generally considered to be sufficient. Rubber wheels

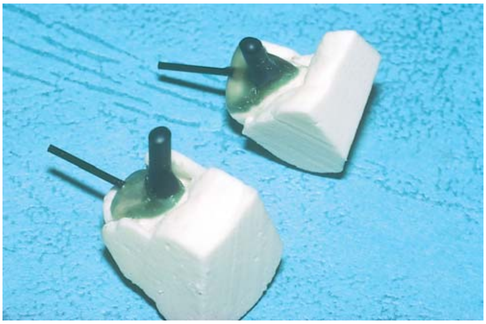

Fig. 9. Lingual view of waxed proximal metal rest and guide plane restorations with plastic bristle added for a handle. The handle will be cut from the casting after bonding and the surface polished.

and points must be used to create a more highly polished surface, and the potential for altering the precisely milled surfaces exists.

When all bonded planes are milled, they are removed from the milling cast and prepared for bonding to their respective abutments. The bonded surface is etched as it would be for any bonded restoration, either by attaching the casting to an electrode and electrically removing metal, etching by the use of an acid gel, or by micromechanical treatment. No technique is clearly superior to the others. The use of bonding agents, 4-META and the like, are indicated, as for any bonded restoration.

One of the problems associated with the addition of bonded surfaces is that the existing partial denture normally cannot be used once the bonded surfaces are added, and the patient must go without the old partial denture until the new restoration is fabricated. When anterior teeth are involved. and some form of temporary replacement is essential, it is practical to convert the old metal partial denture to one made entirely of resin as a temporary restoration. The resin temporary can be easily modified by grinding or adding autopolymerizing resin to allow the patient to wear the prosthesis, even if only for esthetics, but at an obvious additional cost.

Milled surveyed crowns and pontics

With the prototype of the final restoration created in the form of a diagnostic waxup and diagnostic denture tooth setup, the clinician faces several critical questions related to the design of the fixed-removable reconstruction. The issues are abutment selection, choice of restorative material, tooth-reduction requirements for the fixed component, and the attachment mechanism between removable and fixed components of the reconstruction.

The first stage of treatment is tooth preparation and fabrication of the fixed and removable provisional restorations. In preparation for these procedures a tooth-reduction guide must be fabricated [21]. A polyethylene sheet (0.5 mm thick) is pressed over the duplicate cast in the vacuum- and pressure-molding machine. The template is trimmed around abutment teeth leaving 2 mm of the material apical to the gingival margin to prevent it from overseating. Template extensions are preserved over the teeth not requiring modifications, edentulous areas, and the maxillary palate to provide additional stability and orientation. Multiple perforations 1 mm in diameter are created in the template in the areas of the proposed abutment teeth. From time to time during mouth preparation the reduction guide is placed intraorally, and appropriate tooth reduction is verified by placing a periodontal probe through the perforations created in the template and reading preparation depth (Fig. 10). Tooth reduction performed with the guide allows removal of the tooth structure with minimal risk of under- or overpreparation of the abutment teeth.

Tooth-reduction requirements are directly related to the restoration design and choice of restorative material. Rest seats and milled surfaces are fabricated in either type IV gold or ceramo-metal alloys, which require minimal tooth reduction. The space required for these restorations is 1.5 mm, of which 0.5 mm is provided for the metal alloy of the fixed restoration and an additional 1.0 mm is required for the metal alloy of the approximating metal surface of the removable partial denture. These requirements serve only as a guide. When tooth reduction can compromise tooth vitality and structural integrity, clinical judgment should be exercised to modify tooth reduction accordingly. In such situations the required dimension of metal can be gained through slight axial over-contouring of the crown and minor connector to achieve the desired thickness.

Fabrication of the final fixed restorations

A custom impression tray with adequate border extensions is fabricated on the diagnostic cast to capture the preparations and also the proper soft

Fig. 10. Tooth reduction guide placed intraorally over preparations from previous fixed partial denture. Guide showed that no further tooth reduction was indicated.

tissue extensions. A final full-arch impression is completed following conventional prosthodontic protocols. The technique in the production of the master casts is outlined here in detail to ensure efficient fabrication of the final restorations. The first step involves fabrication of the pindexed master cast. A thin coat of baseplate wax (0.5 mm) is placed on the external outer surfaces of the sulcular extensions of the impression material around the tooth preparations. This practice prevents tearing of the sulcular impression material and preserves this extension for the subsequent second pouring of the impression. The impression is poured in type IV dental stone. The fabricated cast is then pindexed, and a base is added. At this point the cast is not yet been sectioned into individual dies, nor is die spacer applied. The next step involves fabrication of the solid cast. This cast is made from a second pouring of the same final impression in a similar fashion using type IV dental stone.

In preparation for the mounting procedures, record bases may or may not be fabricated, depending on the number and location of the teeth in the dental arch. When teeth are well distributed throughout the arch, and the vertical dimension can be maintained with the existing teeth or with sectioned provisional restorations, a record base is not indicated. When distal extensions are present, a record base is usually indicated to support the occlusal registration material in the area of the missing teeth. If a record base is indicated for the mounting of the master casts, it is fabricated on an additional third pouring of the final impression. The record base must be stable and retentive to ensure accuracy during the registration and mounting procedure.

Occlusal registration is made at the established vertical dimension of occlusion. The master casts are now ready for mounting to the articulator. Both the pindexed cast and the solid cast are mounted against the opposing cast in the articulator (Fig. 11). Cross-mounting of the casts of the provisional restorations in addition to the mounting of the master casts is indicated when fabricating multiunit fixed restorations and restorations in

Fig. 11. Pindex and solid master casts fabricated from final impression.

the esthetic area. In such cases diagnostic casts of the provisional restorations are fabricated ahead of time. The obvious advantage of this approach is the transfer to the articulator of important landmarks (eg, incisal and occlusal plane locations, midline angulation) that were previously developed and confirmed with the provisional restorations. The cross-mounting technique has been well described in the dental literature and is not discussed in this article [15,22,23].

At this point the pindexed cast is sectioned to produce individual dies. The individual dies are prepared using common laboratory procedures for finish-line exposure, die protection, and die-spacer application. Next, fabrication of a plastic coping on each of the individual dies is completed using a polypropylene sheet 0.6 mm thick (Hardcast, Scheu Dental, Iserlohn, Germany). The plastic coping is trimmed 1 mm coronal to the finish line (Fig. 12). A wax-separating agent is applied to the die, and the plastic coping is repositioned and roughly marginated with a margin wax. Incorporating the plastic coping in the final waxup allows accurate fit and eliminates potential wax distortion associated with milling and handling procedures.

Plastic copings are then transferred to the solid cast, and the final waxup is completed. At this stage the solid cast is repositioned on the surveying table to confirm the appropriate path of insertion for the removable partial denture, and the tilt of the master cast is preserved with tripod marks (Fig. 13). Silicone putty indices for use in the application of veneering materials are fabricated around the waxup and keyed to the master cast. Planned occlusal rest seats and undercut areas for any retentive clasps arms are created in wax, and the depths are verified.

The final waxup can be milled with wax milling burs on a milling machine or with the wax-milling blade of the dental surveyor. This second option does not require expensive equipment in the form of the milling machine, but it is possible to achieve more precise finish of the wax and metal surfaces using the milling machine. In both cases, the tilt of the solid cast is preserved

Fig. 12. Plastic coping fabricated on individual die and trimmed 1 mm coronal to finish line.

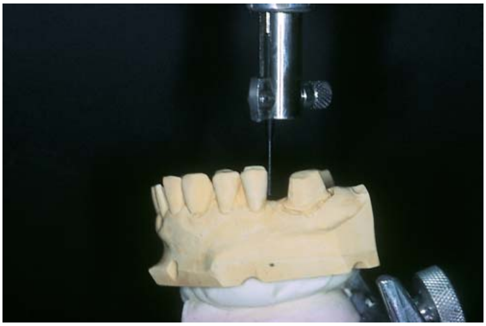

Fig. 13. Solid cast repositioned on survey table to confirm path of insertion.

in the surveying table while the wax milling is performed. The vertical extent of the milled surfaces is usually limited to the coronal two thirds of the fixed restoration. This practice prevents encroachment of the removable partial denture on the gingival tissues and allows preservation of the emergence profile of the fixed restorations. If a lingual/proximal ledge is indicated in addition to the vertical milling, it is performed with the milling bur/milling blade (Fig. 14). The thickness of the ledge is kept to 1 mm. In interproximal areas adjacent to pontics or between splinted restorations, special consideration must be given to the connector area to allow for the adequate thickness and maintain rigidity of the framework. A minimum joint size of 2 mm horizontally and 3 mm vertically must be maintained.

A cutback of the waxup is performed in the areas to be veneered with the ceramic material, and the desired reduction verified with the silicone putty index is keyed to the master cast (Fig. 15). Reduction requirements of the cutback for ceramic veneers are 1.0 to 1.2 mm. Special consideration is given to the external finish line of the proposed ceramo-metal junction. If placed occlusally, the ceramo-metal junction should be at least 1.5 mm away from the occlusal contacts and 0.5 mm from any occlusal rest seats. Proximally,

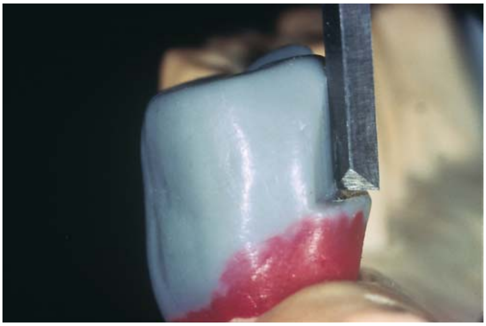

Fig. 14. Final waxup milled on dental surveyor to create lingual ledge rest and guide plane.

Fig. 15. Final cutback verified with silicone putty matrix keyed to solid cast.

the external finish line is located slightly (0.5 mm) beyond the facial line angle of the fixed restoration, allowing for maximum breadth of the guide plane for milling and potentially minimizing the risk of veneering ceramic fracture. At this point wax patterns are ready for final margination on the individual dies, investing, and casting in the appropriate alloy.

Following ceramic application, final milling of the metal surfaces is performed on the solid cast placed on the surveying table at the previously established tilt (Fig. 16). The surface contour established by a fine-cut milling bur appears polished, and any additional polishing with rubber wheels and abrasive polishes that would be used for the conventional finished surface of the metal in a normal crown does not seem to offer any additional advantage. The remainder of the metal surfaces are finished and polished at this stage.

Final milling is best done on a solid cast, which contains all the fixed components. The same cast will be used for the fabrication of the partial denture framework if all edentulous landmarks are present. If this master cast is inadequate for the construction of the partial denture in regard to

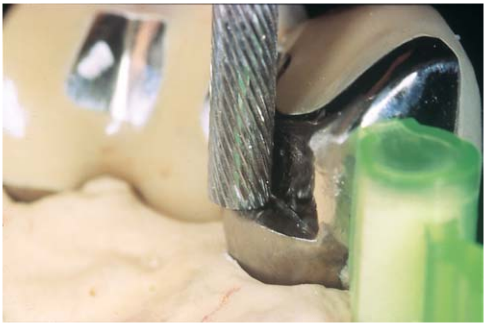

Fig. 16. Final milling with fine milling bur on solid cast.

accuracy or extensions, a pick-up impression of the fixed components must be made. A properly extended custom tray must be used for this impression.

Individual resin dies, made before the impression, are inserted into the crowns in the impression and locked into the resultant stone cast using a brass die pin that has been incorporated into the resin (Fig. 17). To make the die, pattern resin or a similar product is placed into the lubricated crown, and the die pin is centered into the resin before polymerization. Care must be taken to protect the margins of the restoration by not extending the resin over the margin, especially when butted porcelain is used. The impression material of choice for the pickup final impression is one that is both accurate and relatively rigid. These materials, such as Impregum F (Espe, Seefeld, Germany), are so rigid that fracture of the tooth portion of the final cast or the veneering porcelain is a distinct possibility when the impression is removed from the set stone. The most appropriate material for the custom tray is an autopolymerized acrylic resin because it can be softened with heat before removal (Fig. 18). The completed crowns remain on the master cast through duplication and fitting of the partial denture framework but are removed before the partial denture is waxed to place on the cast for investing (Fig. 19).

When recontoured natural teeth, bonded restorations, and milled crowns are combined in the same arch, picking up the crowns in the final impression may not be practical, depending upon the number of crowns involved. In such situations, cementing the crowns, either temporarily or permanently, before a regular final impression is usually indicated. The only disadvantage to this alternative is that the fitting of the framework must be done in the mouth rather than on the cast to obtain the most ideal tooth–frame relationship.

Fig. 17. Resin dies with bent guide pin to be placed into crowns after pickup impression. Internal surface of crown must be well lubricated with petroleum jelly or a similar product before pouring the resin.

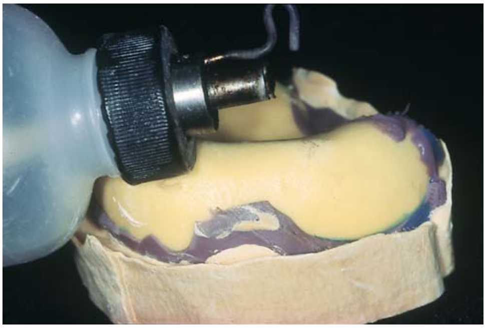

Fig. 18. Autopolymerizing resin tray softened with flame to facilitate its removal from cast.

Partial denture casting control

Axial surfaces, milled to perfection, are only half of the equation [24]. The framework must have maximal possible contact with the milled surfaces so that they function as precision attachments. There are three areas where the dental laboratory can dramatically alter the fit of the framework against the milled surfaces.

Blockout

Because the milled surfaces have been created on a milling machine or a dental surveyor, no areas of undercut should be found on these prepared surfaces. Therefore, there is no reason ever to place blockout wax on either the milled surfaces of the crowns or on the stone teeth of the master cast in areas where milling has been used. Any wax placed upon these surfaces obviously alters their dimensions, and attempts to remove wax will either

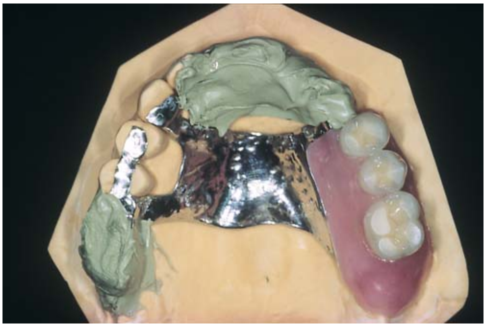

Fig. 19. Fixed components removed from cast before investing. Laboratory silicone putty placed over abutments to contain processed resin.

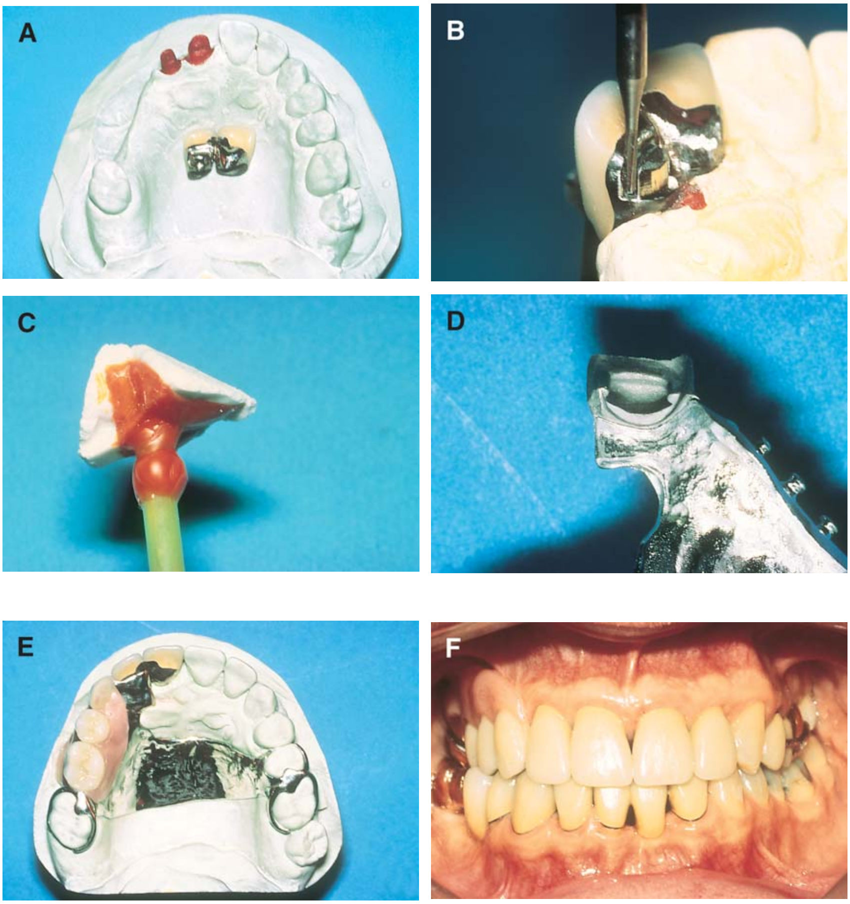

Fig. 20. Milling the lingual surface of a single anterior restoration. (*A*) Milled crowns removed from the master cast showing resin cores. (*B*) Final milling of lingual surface of anterior abutment. (*C*) Lingual milled rest waxed upon a refractory die and sprued. (*D*) Cast milled rest after soldering to framework. (*E*) Completed partial denture ready for flasking. (*F*) Esthetic restoration without visible anterior retention.

leave a small film or scrape the stone tooth. In either case, the accuracy of the master cast will be affected.

Refractory cast

Accuracy of the cast metal depends on the expansion of the refractory cast. It has been stated that even an error of ± 1 mL of liquid will alter the powder/liquid ratio so that a discrepancy can be seen clinically [25]. The dental laboratory must pay the highest level of attention to the accurate measurement of both powder and liquid when pouring the duplicated refractory cast.

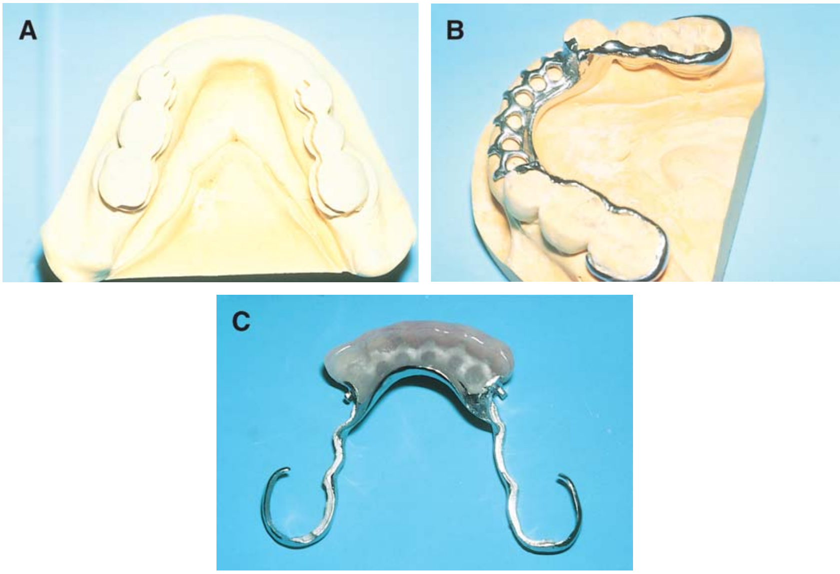

Fig. 21. Simple milling of posterior teeth for the class IV partial denture. (*A*) Lingual milling of fixed partial dentures. (*B*) Completed framework with posterior major connector within crown contours. (*C*) Tissue surface view of completed partial restoration showing ideal milling contours and resting surfaces.

Metal finishing

The greatest possibility of error in the creation of a precise fit between the milled surface and the casting occurs through the procedures employed in the finishing and polishing of the framework [14]. The uncontrolled loss of metal that normally occurs in the fitting phase dramatically alters the fit of the casting to the milled surface. Every effort must be made to leave the internal surface of the casting in the as-cast condition in the areas of desired contact with the milled surfaces. The laboratory must neither electrostrip these surfaces nor grossly grind them to fit the frame to the master cast. Rather, the fitting of the frame must be first done in the mouth with all restorations present.

Before final fitting, either in the mouth or on the master cast if all abutment restorations are in place, the internal tooth-contact surfaces of the casting are first examined under the laboratory microscope for blebs, and these are carefully removed with minimal reduction of metal. The casting is then taken to the mouth with its internal surface coated with a disclosing material (Fit Checker, GC International Corp., Scottsdale, Arizona). Gross interferences are readily identified, and those contacts are removed from the framework. Final fitting is best accomplished using Mylar-based articulating tape (Accu-film, Parkell, Farmingdale, New York), roughly 30 μm thick,

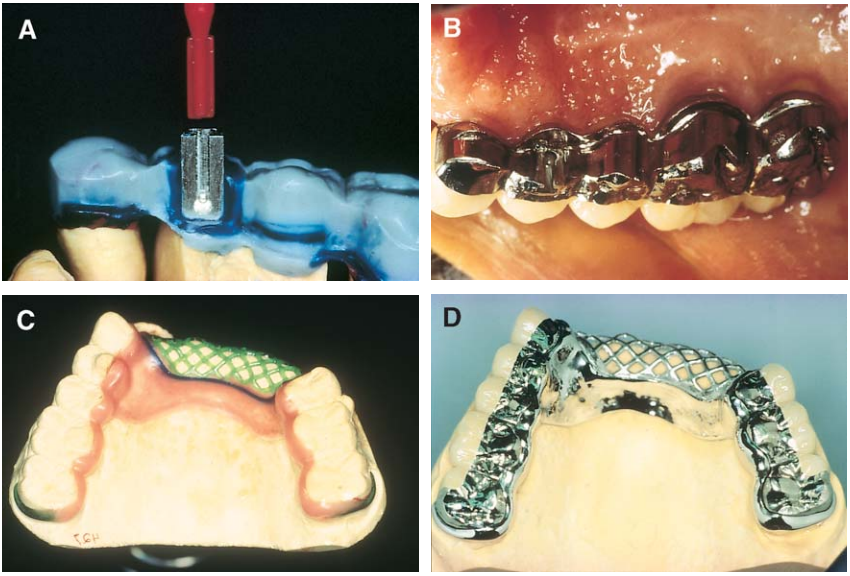

Fig. 22. Complex milling with precision attachment for maxillary class IV. (*A*) Matrix of precision attachment placed into pontic with milled lingual surfaces. (*B*) Completed fixed component temporarily seated before pickup final impressions. (*C*) Waxed framework on refractory with posterior distolingual retentive clasp arms. (*D*) Finished casting with minimal palatal coverage.

which is placed inside the casting. When the casting is seated by rocking it into maximal contact with the teeth, the areas of hypercontact can be easily identified from the deposit of the dye.

Only when the tooth–frame relationship has been established as acceptable is the casting seated upon an all-stone master cast. At that time the stone cast is altered to allow complete seating; the casting is never altered. The resulting tooth–frame relation will be as ideal as possible given the materials that exist at this time. Final finish and polish of the internal surfaces of the casting are completed without altering in any way the guiding plane surfaces that would contact the milled components. The metal gingival to these guide planes receives the highest possible polish to reduce plaque accumulation.

Clinical examples of the milling process

Milling the lingual surface of a single anterior restoration

Anterior visible clasping can often be completely eliminated when milled surfaces can be established on a tooth or teeth adjacent to an anterior edentulous space. When the milled surfaces can be made parallel to

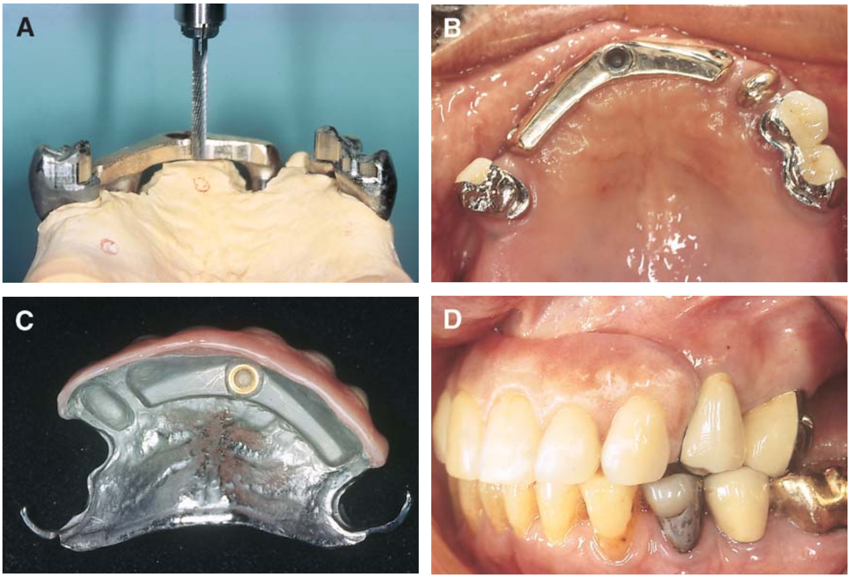

Fig. 23. Milling of lingual surface of implant bar and lingual surfaces for maxillary class IV. (*A*) Milling of lingual surface of bar parallel to the guide planes established on the lingual and distal surfaces of the crowns. (*B*) Completed fixed restorations in mouth. (*C*) Internal view of removable partial denture showing posterior cast clasps and single attachment into bar. (*D*) Lateral clinical view showing ideal esthetics with conventional clasp at the distal facial surface of the posterior abutment.

posterior guide planes, conventional clasping of the posterior teeth can retain the partial denture, and the milled surfaces eliminate any tendency for the anterior segment to rotate away from the abutment teeth. Because the milling is confined to the lingual surface, no evidence of the partial denture other than the gingival acrylic will be visible (Fig. 20).

Simple milling of the lingual surfaces of posterior teeth in the mandibular class IV

Milled lingual surfaces created using only the dental surveyor blade in the waxed restorations can create precise parallelism (Fig. 21) even without the use of a milling machine. The resulting milled surfaces are irregular in the horizontal plane, but the vertical parallelism isolates the path of insertion/removal and restricts the use of conventional clasping to the most posterior teeth only. It also is possible to place the major connector entirely within the contours of the milled restorations and thereby eliminate framework extensions into the floor of the mouth.

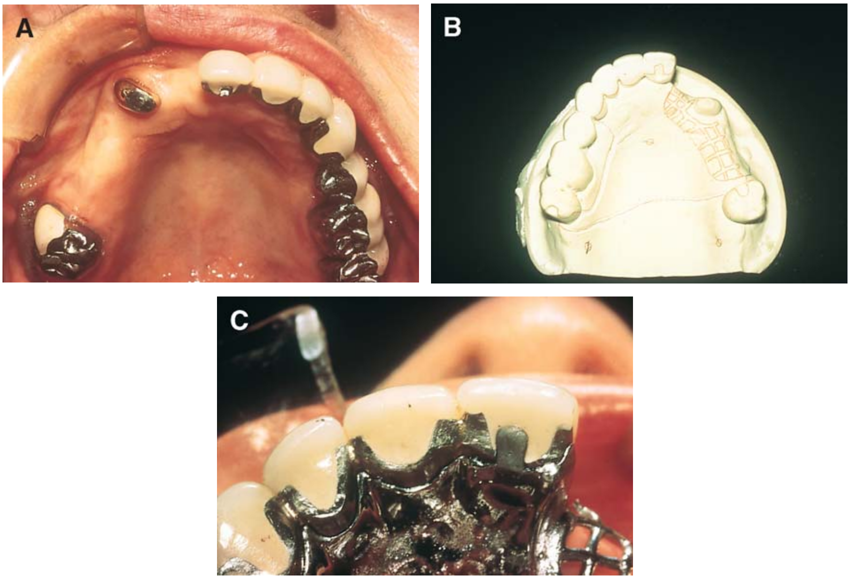

Fig. 24. Milling in a repair situation. (*A*) Failure of long-span fixed partial denture with semiprecision box cut into the lingual surface of right central pontic. Box has been cut parallel to mesial guide plane of second molar. (*B*) Designed master cast with appropriate beading of palatal tissues. (*C*) Partial denture casting seated into milled recess.

Complex milling with precision attachment for maxillary class IV

Large class IV situations in the maxilla can greatly benefit from full lingual milling. The traditional maxillary major connector can be eliminated, and the majority of the palate can be freed from coverage. Fig. 22 shows the combination of a precision attachment, Stern's gingival lock, and full-lingual milling with conventional clasping on the most posterior teeth. The partial denture is fully supported against movement toward the tissue in mastication and is highly retentive because the path of removal is so precise.

Milling of implant-connecting bar and remaining posterior teeth for maxillary class IV

When implants are connected by a bar, great precision can be obtained by milling the lingual surface of the bar (Fig. 23). Conventional clasping on one posterior tooth on each side is more than sufficient to retain the partial denture, and the milled bar provides a vertical stop as well as restricting the path of removal. Additional retention can be placed in the bar if desired.

Milling in a repair situation

A form of milling can be used to create a semiprecision–attachment partial denture as a repair of a failed full-arch fixed restoration. When an anterior pontic exists and the occlusal relationship allows, a semiprecision dovetail can be cut intraorally in the lingual surface of the pontic. This matrix will receive a patrix, either as a component of framework or as an individual casting that is later attached to the frame with solder or laser welding. Any posterior guide planes should be prepared first to determine the path of removal, and the matrix should be cut to that path. The semiprecision attachment in combination with conventional posterior clasping eliminates the need for anterior visible clasping (Fig. 24).

Summary

The creation of milled parallel surfaces in natural or restored abutment teeth, coupled with removable partial denture castings that have optimal contact with these preparations, results in a path of insertion and removal that is controlled in a manner similar to one using conventional precision attachments. Because the milled surfaces are primarily extracoronal, little, if any, additional tooth reduction is required for adequate mouth preparation. Avoiding additional tooth reduction minimizes later abutment fracture. The great increase in stability and resistance to rotational movements, when combined with conventional posterior clasping, provides a reasonable alternative to the precision attachment in providing maximal esthetics for the partially edentulous patients.

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