Incisal Morphology and Mechanical Wear Patterns of Anterior Teeth: Reproducing Natural Wear Patterns in Ceramic Restorations

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The wear and fracture patterns of natural teeth can serve as a guide regarding the risks faced by dental restorations in the anterior region. The rule "form follows function," which is commonly applied to tooth morphology, can also be applied to normal wear patterns and chipping/fracture tendencies. Some incisal edge designs for ceramic restorations are more likely to chip than others and may cause harm to the opposing natural teeth. Reproducing a patient's natural wear patterns in ceramic restorations may improve success and survival rates. This article describes the natural wear and chipping patterns of maxillary and mandibular incisors. Guidelines are suggested for the strategic design of the incisal edges of ceramic restorations to minimize cohesive ceramic chipping. *(Am J Esthet Dent 2012;2:98–114.)*

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Tooth attrition will occur in varying degrees throughout an individual's life, even with proper tooth alignment and an adequate occlusal relationship.[1] By the time they reach old age, some patients may have worn completely through their incisal enamel, while others may still present with mamelons at the incisal edges of the anterior teeth.[2] The shape and amount of wear depend on a number of factors, including the magnitude, direction, and frequency of force applied during tooth-to-tooth contact. However, common wear patterns can still be identified and described. A growing number of studies have expressed concern regarding the chipping of veneering porcelain in ceramic restorations.[3–7] Cohesive chipping does not necessarily lead to restoration failure (end of service life), but it can be a precursor to further incisal chipping, fracture, bond failure, esthetic liability, and patient dissatisfaction (Fig 1).

As with ceramic restorations, natural incisors may chip at the incisal edges (Fig 2). There appears to be a relationship between the anatomical shape of wear facets on incisal edges and their likelihood of chipping. Therefore, studying the function and attrition patterns of natural teeth may be a way to gain insight regarding the outcomes of restorations placed under similar circumstances.

Treatment planning for any restorative procedure should include an assessment of risk. Kois[8] categorized dental treatment risks into four groups: biomechanical, periodontal, dentofacial, and functional. Evaluating preoperative wear provides a good estimate of the functional risk to a prospective anterior restoration. The more preoperative wear, the higher the risk.[9] When evaluating occlusal attrition, it cannot be assumed that all lost tooth structure resulted from tooth-to-tooth contact. There are several processes that can lead to loss of occlusal/incisal tooth structure. It is important to differentiate between these processes as well as consider the possible additive effects of each process on the total loss of tooth volume.

Fig 1 Incisal chipping of the veneering porcelain.

Fig 2 Incisal chipping of a natural tooth.

LOSS OF TOOTH STRUCTURE

Abrasion, erosion, trauma, attrition, and congenital malformations such as amelogenesis and dentinogenesis imprefecta and dentinal dysplasia are the main mechanisms that cause loss of tooth structure.[10–16] All of the these mechanisms can occur concomitantly (Fig 3).

Abrasion

Abrasion involves mechanical wear of any tooth surface that comes in contact with an exogenous abrasive agent, including unrefined food products that may contain grit or sand, abrasive toothpastes, chewing tobacco, etc. Abrasion does not require tooth-to-tooth contact and yields an unpolished matte surface in areas free of tooth contact. Exposed dentin will scoop.[16]

Fig 3 Tooth loss by attrition *(a)*, trauma *(b)*, and erosion *(c)*.
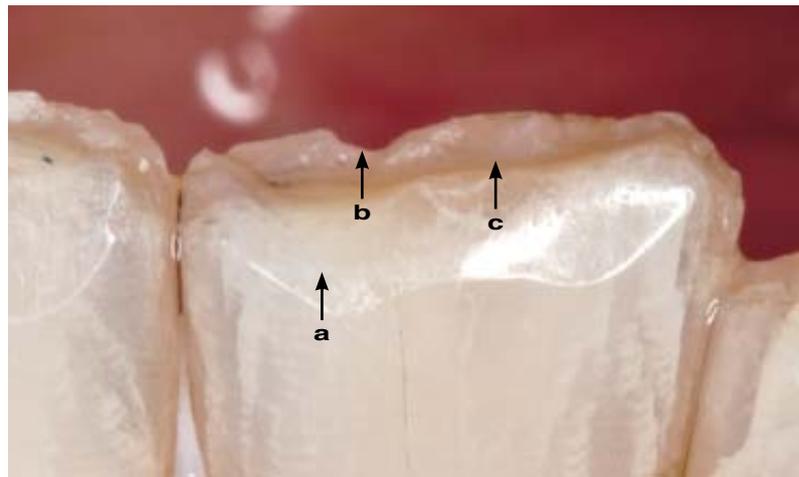
Traumatic fracture

Traumatic fracture is the splintering or breaking of a portion of the tooth caused by collisions of various types. Trauma, nonparafunctonal gritting, unintentional tooth-to-tooth collisions, or crunching can be episodic or habitual. Some individuals habitually chew hard objects (eg, ice, fingernails, pens) and create micro- or macrofactures. The brittle nature of enamel allows for the inception of flaws, cracks, or fractures under elastic/inelastic deformation or contact loads. Studies of the mechanical properties of enamel show that crack propagation is influenced by enamel rod orientation, distance to the dentinoenamel junction, and age.[17–19]

Erosion

Erosion or corrosion is the progressive loss of tooth substance by chemical processes that do not involve bacterial action, producing sharply defined defects.[20–22] Erosion occurs when acidic agents contact the tooth surface, such as with highly acidic foods or beverages, certain medications (eg, aspirin, antihistamines, vitamin C chewing tablets), gastroesophageal reflux disease, and frequent vomiting from bulimia or alcoholism. Accelerated erosion also occurs in patients with reduced salivary flow, such as due to Sjögren syndrome or to side effects from some prescription medicines. The clinical manifestation of erosion in the posterior segment involves occlusal cupping, ie, sunken areas that do not have occlusal contact.[23,24]

Attrition

Attrition is the process of wearing or grinding down tooth structure via friction from opposing tooth surfaces when a mechanical force is applied.[20,25] Attrition is typically characterized by a

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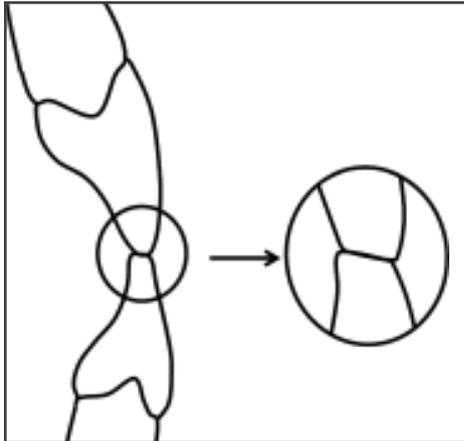
Fig 4 Rounded opposing incisal edges rub against each other and cause wear over time. Flat facets are created on the edges.

Fig 5 Crossover (edge-to-edge) incisal wear by attrition. The large amount of lost tooth structure indicates a high biomechanical risk for any prospective restoration.

facet that is matched by a corresponding facet on the antagonist tooth. When dentin is exposed, it remains flat with no cupping or scooping.[16] Abrasion, erosion, and traumatic fracturing will all accelerate tooth loss by attrition.

NATURAL WEAR PATTERNS

Dentitions with Angle Class I and II, division 2 malocclusion show anterior tooth-to-tooth wear mainly on the palatal-incisal surfaces of the maxillary incisors and the buccal-incisal edges of the mandibular incisors. Incisal edge wear occurs when the mandible moves laterally, anteriorly, or lateroprotrusively and the maxillary and mandibular incisors contact in a "crossover" or edge-to-edge position. Rounded opposing incisal edges rub against each other and cause wear over time (Fig 4).[26] Edge-to-edge contact does not usually occur during normal mastication or phonation. Contact between opposing incisal edges can occur during sleep (ie, bruxism) or sleep apnea protrusive thrust events[27–31] and throughout the day while bracing for contact in sports, clenching, etc.

Over time and with millions of cycles of tooth-to-tooth crossover contact, rounded incisal edges wear flat and develop facets (Fig 5). These antagonistic incisal facets develop on both the maxillary and mandibular incisal edges. This opposing edge symmetry is sometimes known as a "lock and key" fit. The greater the frequency and magnitude of these opposing forces, the broader the wear facets become.[11]

Fig 6   Leading edge beveling or wear *(a)* on the buccal-incisal surfaces of the mandibular incisors. Incisal edge wear *(b)* is also evident.
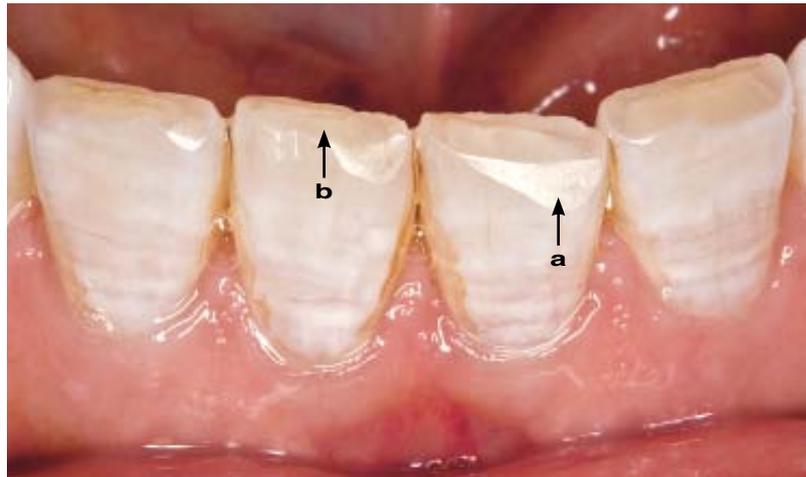
Fig 7   Incisal edge wear *(c)* and lateroprotrusive palatal wear *(d)* on the maxillary incisors.
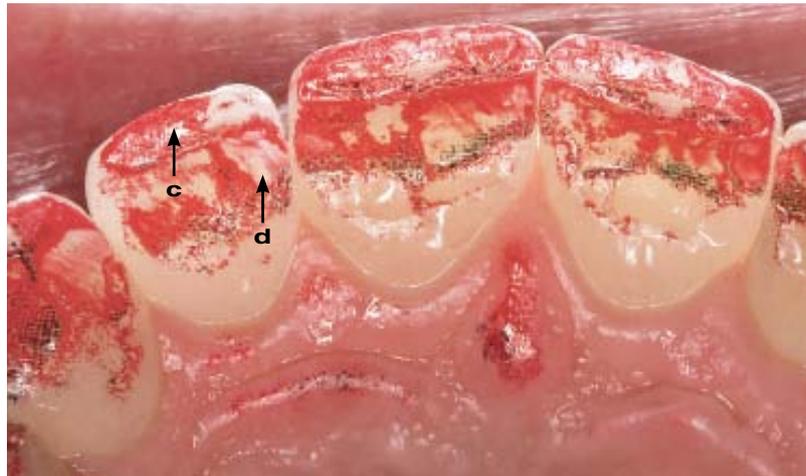
Leading edge wear

When there is coupling of mandibular incisors against maxillary incisors (Angle Class I and II, division 2) during mandibular lateroprotrusive or protrusive movements, the influence of the contacting tooth surfaces guides the movement of the mandible. Contact and wear occurs between the palatal surfaces of the maxillary incisors and the leading or buccal-incisal edges of the mandibular incisors (Figs 6 and 7).

The amount and three-dimensional topography of the resultant wear facets will vary depending on the tooth arrangement, Angle classification, and influence of the condylar inclination on the mandibular movements.

Trailing edge wear

Trailing edge wear occurs when opposing anterior teeth move into distant crossover beyond the incisal edge-to-edge position. Trailing edge wear facets

Fig 8 Dentition with heavy crossover wear of the anterior teeth.

Fig 9 When the mandible extends lateroprotrusively past the canines, the guidance and occlusal load often passes from one set of coupled incisors to the next.

are rare. Unlike leading edges, tooth-to-tooth contact that naturally bevels the trailing edges is rare. To establish a trailing edge wear facet, there must be vertical rubbing between a mandibular lingual-incisal edge and a maxillary labial-incisal edge beyond an edge-to-edge position. Most distant crossover movements have lateral directionality. Typically, when the mandible makes an extended lateroprotrusive movement past the canines, the occlusal load passes from one set of coupled incisors to the next, which limits the opportunity for vertical rubbing (Figs 8 and 9). Crossover wear tends to sharpen trailing edges, while wear on the leading edges will be rounded or have beveled facets.
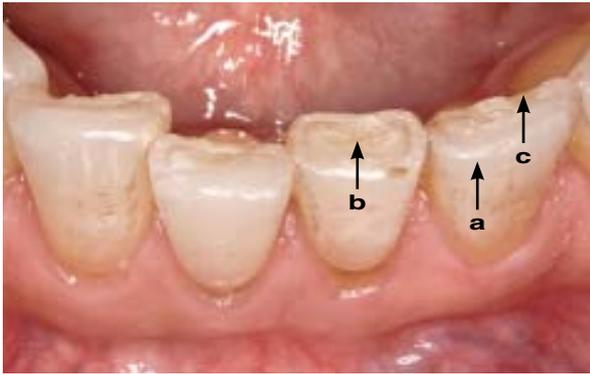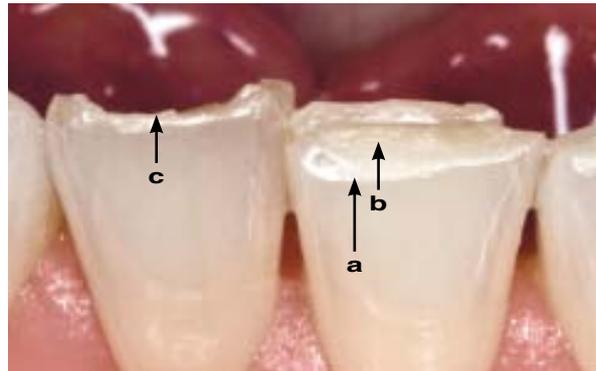
Fig 10 Mandibular incisors with leading edge wear *(a)*, incisal edge wear *(b)*, and trailing edge chipping *(c)*.

Fig 11 Trailing edges typically chip more than leading edges in both natural teeth and ceramic restorations.

**Fig 12** Trailing edge chipping of a maxillary incisor.

Fig 13 Mandibular incisors with leading edge wear *(a)*, incisal edge wear *(b)*, and trailing edge chipping *(c)*.

Incisal edge chipping

Incisal chipping can occur as a result of both trauma and attrition. In the authors' experience, incisal chipping occurs predominantly on trailing edges. Incisal chipping is likely to occur in the same locations in both natural teeth and ceramic restorations (Figs 10 to 13). Such chipping usually occurs on the buccal-incisal edges of the maxillary incisors and the lingual-incisal edges of the mandibular incisors. The internal forces that result from incisal rubbing explain this tendency. The leading edges are subject to compressive loads. Enamel and porcelain have high compressive load strength and low tensile load strength.[32] The trailing edges are subjected to shear forces.
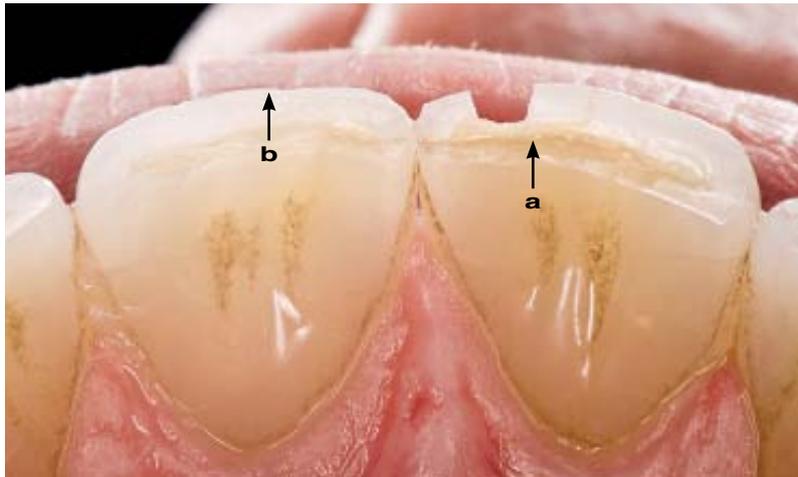
Fig 14 Erosive areas *(a)* on incisal edges of natural teeth can create a snag that increases the likelihood of trailing edge chipping. Smoothening the entire incisal facet and decreasing the topographic prominence at the trailing edges *(b)* will reduce the risk of chipping.
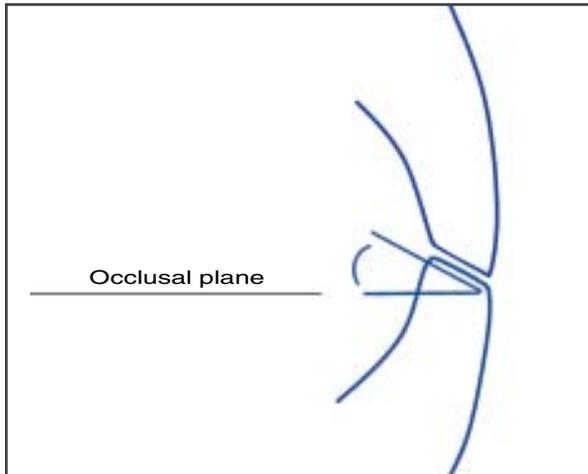
Occlusal plane

Fig 15 The angle of the facet relative to the occlusal plane will vary depending on the direction of the mandibular movement during edge-to-edge contact. Tribologic studies show that the facet planes will be parallel to that movement.

Figure 14 shows trailing edge chipping of a natural incisor. The buccal-incisal edge in this example may have been more prone to chipping due to the following factors: lack of dentin support, inside-out shear rubbing forces, heavier contact on the trailing edge created by the evolving erosive concavity, traumatic protrusive thrust of the mandible, and sharp unbeveled edges. In the authors' opinion, all of these factors could have been minimized by buffing, beveling, or decreasing the topographic prominence of the trailing edges. Smooth surfaces are less likely to catch and create shear forces. Incisal chipping in both natural teeth and ceramic restorations can be significantly reduced by buffing, beveling, or rounding the trailing edges and by smoothening any rough areas or snags that can get caught on opposing edges.

Angle of incisal wear facets

There is no "normal" angulation of the incisal wear facet relative to the occlusal plane or condylar inclination (Fig 15). The authors' experience shows that the

Fig 16   Low-angle incisal edge facets.

Fig 17   High-angle incisal edge facets.

angle can vary from below the level of the occlusal plane to very steep or knife edged (Figs 16 and 17). The facet angle varies depending on the direction of the movement of the mandible when the edges are in contact. The wear facets will develop parallel to the mandibular movement. The mandibular movement is determined by a combination of the condylar and anterior guidance, which can be modified by clinicians to a limited extent.

Fig 18 Heavy leading edge wear with limited crossover incisal edge wear. Note the trailing edge chip on the right central incisor.


Fig 19 The mandibular left lateral incisor has complex and heavy incisal edge wear facets created by right and left crossover movements with limited leading edge wear.

Wear ratios between incisal and leading edges

The amount of wear on the different surfaces of anterior teeth will vary depending on several patient-specific factors. The frequency of each attrition-causing contact as well as the direction and magnitude of the force applied determine the amount of lost tooth structure. The ratio of leading edge wear to incisal edge wear will also vary from case to case (Figs 18 and 19). It is the authors' observation that some individuals rarely move the mandible into distant excursive movements/crossover with much force and thus show little or no incisal edge wear. Such individuals may present with only leading edge wear, while others may show the reverse.
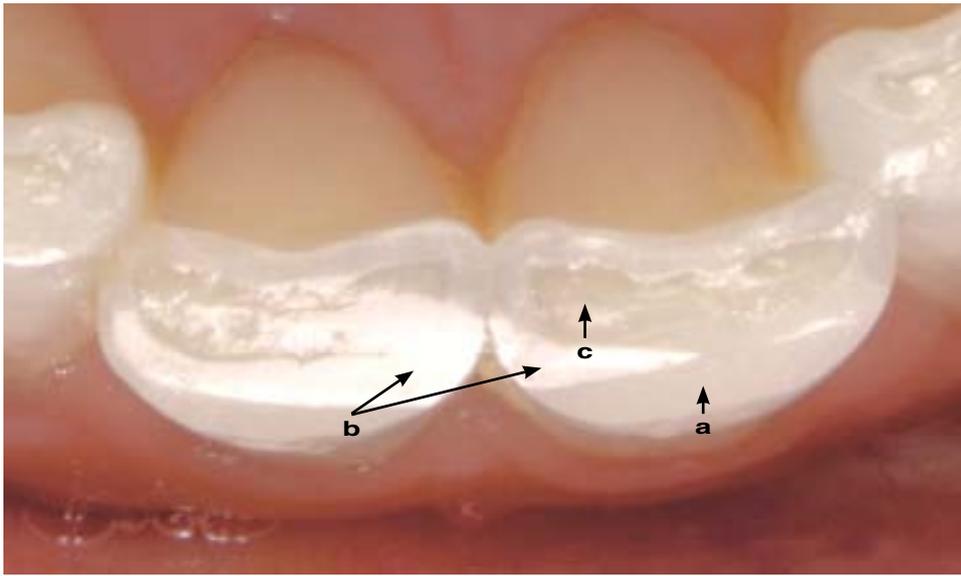
Fig 20 Wear can tell you what the patient does with his or her teeth. Protrusive leading edge wear *(a)*, left-working incisal edge crossover wear *(b)*, and right-working incisal edge crossover wear *(c)*.

There are anatomical factors that dictate how opposing teeth contact each other. There are also behavioral tendencies that influence wear patterns. The habitual movements of the mandible determine how wear manifests in each individual.

TOOTH WEAR AS A DIAGNOSTIC TOOL

Wear can be used as a diagnostic tool to assess habitual movements and functional risks of prospective treatment. Preoperative loss of incisal tooth structure can be diagnosed and evaluated using the follow steps:

1. The wear facets should be observed in close detail to determine the patient's habitual movement patterns and assess potential risks (Fig 20). Antagonist facet planes will always be parallel to each other.
2. If opposing wear facets do not align, the clinician should look for another surface facet as the true antagonist.
3. If a patient is accustomed to a distant left-working movement or position while bracing preoperatively, that same movement will likely occur after treatment. The shapes of the preoperative facets indicate the direction of such movement, and the amount of wear indicates the frequency and/or force that is applied.
4. Creating a custom incisal guide table is an excellent way to document the habitual excursive pathways prior to fabricating a diagnostic wax-up.[33–35]
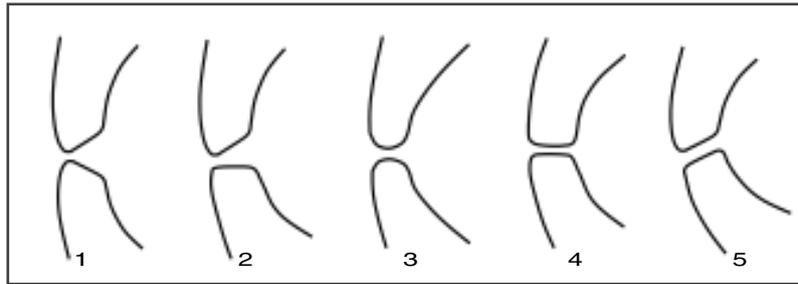
Fig 21 Five examples of edge-to-edge relationships. Increased stability is achieved when the final facet angles of the restorations match their opposing natural facets. Therefore, example 4 or 5 would be the most stable relationship depending on the preoperative facet angle.

Designing stable edge-to-edge relationships

There are two characteristics of incisal edge-to-edge facet relationships that make them less prone to chipping: The antagonist facets should be parallel to each other, and the facet plane angles should be parallel to the mandibular movement at the time of contact. The wear facet that forms between two objects that are rubbing together will develop parallel to that movement.

Figure 21 shows five different examples of edge-to-edge relationships. The last two options shown both satisfy the condition of being parallel to each other. To determine the more stable relationship between these two for a particular patient, diagnostic casts should be evaluated. The facet angles relative to the occlusal plane for each restoration should be roughly the same as those found on the diagnostic casts.

Any orthodontic or prosthetic alteration of the anterior guidance may also change the direction of mandibular movement and thus the wear facet angles. Small differences will occur when the buccal-lingual positions or lengths of the teeth are altered. When fabricating new restorations, the dental technician should consider designing an incisal shape that is harmonious with the opposing working surfaces by approximating the facet angles found on the mounted diagnostic casts. After delivery of the definitive restorations, the clinician can confirm, refine, and smoothen the three-dimensional parallelism of the edges in excursive movements, effectively "re-faceting" the edges. This technique could be used for equilibration of natural teeth as well.

Postinsertion adjustment

Unaligned tooth surfaces that rub against each other have an increased possibility of chipping. It is the authors' opinion that if posttreatment ceramic edges are not parallel to their antagonists or have uneven or rough surfaces, greater forces will be exerted on both the restorations and opposing natural teeth (Fig 22).

The purpose of the postinsertion adjustment is to align and smoothen the antagonist facets so that they are flat

Fig 22 Incisal chipping of a recently placed crown. The restorative dentist made no attempt to adjust the incisal edges to match the opposing edges. Small chips occurred shortly after placement. All opposing edge contacts in all excursive movements were marked with blue ink. The arrows indicate trailing edge chips. Heavier inking outlines the chipped areas.
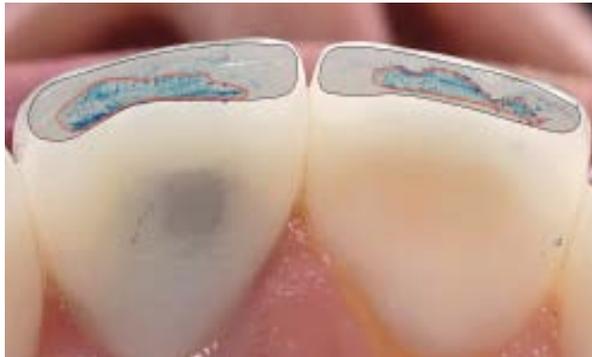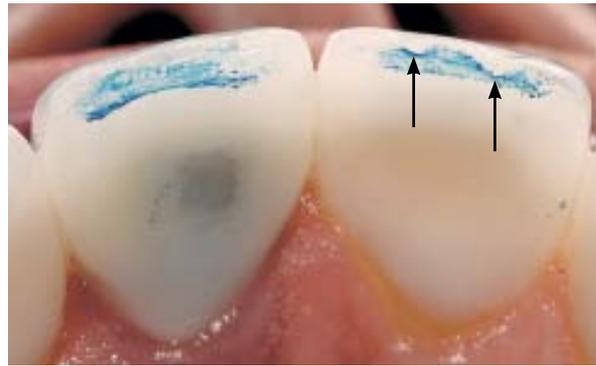
Fig 23 The preoperative incisal edge area that contacts the opposing edges *(outlined with red)* is too small and rough. Restoration longevity and stability can be improved by flattening and broadening the incisal facet contact zones from the areas outlined in red to the areas outlined in blue.
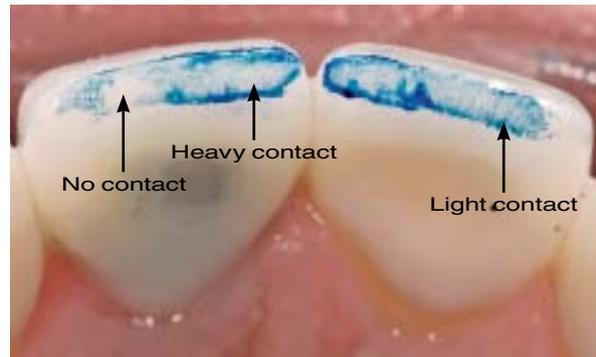
Fig 24 No contact areas will be devoid of ink. Heavy contact areas will show a very thin layer of ink; medium contact areas will have medium to thick ink coverage. The lighter the contact, the thicker the ink.

and parallel to each other in every excursive movement identified from the diagnostic casts. The greater the preoperative edge wear or facet size, the broader the incisal edge facets should be in the definitive restorations. Distributing the load over a larger area decreases the load per square millimeter. Studies show that larger contact facet sizes are more fracture resistant and have increased load-bearing capacity in all-ceramic crowns.[36,37]

The step-by-step clinical procedures for postinsertion adjustment are as follows:

1. Evaluate the three-dimensional parallelism of incisal facets use heavy-ink articulating paper (0.008 inches [200 µm]; Bausch Blue Articulating Paper Strips, no. BK-01, Pulpdent) or ribbon to mark edge contacts in all crossover positions. It is common to see heavier inking near or outlining trailing edge chips.

2. Broaden the incisal facets. To improve the parallelism between antagonists, adjust the areas (Figs 23 and 24) marked with ink using a diamond-impregnated slow-speed abrasive wheel (LD15M LD Grinder

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Fig 25 If the opposing natural edges are chipped, rough, and/or uneven, they should be smoothened and polished using the same inking technique.

Pink Medium Wheel, Brasseler). When adjustment is limited to the inked areas, repeated polishing will slowly increase the facet size. Place the wheel parallel to the incisal facet over the heavy contact areas to reduce them to medium or light contact. The goal is to have as even a spread of ink as possible over the entire facet.

3. Learn to read three-dimensional inking. There are three levels of contact: no contact, light contact, heavy contact. Remember that incisal edge facets may have subfacets resulting from contact in different excursive movements.

4. Place a small buffed bevel on both the buccal and lingual edges to prevent snagging and smoothen the lateral crossover transitions.

Poor tooth alignment can increase the likelihood of chipping. Orthodontic realignment of the opposing teeth improves the likelihood of smooth excursive transitions. When orthodontics is not approved by the patient, this faceting technique can make the opposing natural edges less harmful to the definitive restorations (Fig 25).

CONCLUSIONS

The excessive loss of tooth structure due to mechanical attrition represents a biomechanical and functional risk for dental restorations. This article described the wear patterns of natural incisors and the potential consequences of such wear on natural teeth and ceramic restorations. Clinicians should learn to strategically design the incisal edges of metal-ceramic and ceramic restorations to minimize the likelihood of chipping and to decrease damage to the opposing natural dentition. Natural wear patterns should be reproduced by clinicians and technicians during the fabrication of restorations. Preoperative wear patterns of the anterior dentition may serve as a guide to assess the risk of chipping and fracture posed to the definitive dental restorations.

ACKNOWLEDGMENT

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